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STUDIES IN AUSTRALIAN THYSANURA
NO. 4 MACHILIDE (BRISTLE-TAILS)

BY *H. WOMERSLEY*

Summary

The *Machilidae* or Bristle-tails, together with the *Lepismatidae* or Silverfish, form the ectotrophic division of the old order Thysanura. Apart from several primitive characters, however, they have very little in common with the entotrophic division which includes the families *Campodeidae, Japygidae* and *Projapygidae.* The present tendency of taxonomists is to regard them as two distinct orders, the *Ectotrophi* (*Thysanura*. str.) and the *Entotrophi (Diplura).*

TRANSACTIONS OF THE ROYAL SOCIETY OF SOUTH AUSTRALIA INCORPORATED

STUDIES IN AUSTRALIAN THYSANURA

No. 4. MACHILIDAE (BRISTLE-TAILS)

By H. Womersley, F.R.E.S., A.L.S.

[Read 11 November 1937]

The *Machilidae* or Bristle-tails, together with the *Lepismatidae* or Silverfish, form the ectotrophic division of the old order Thysanura. Apart from several primitive characters, however, they have very little in common with the entotrophic division which includes the families *Campodeidae, Japygidae* and *Projapygidae.* The present tendency of taxonomists is to regard them as two distinct orders, the *Ectotrophi (Thysanura* s. str.) and the *Entotrophi (Diplura).*

The two families of the *Ectotrophi* may be separated as follows:—

Compound eyes large; ocelli present. Abdominal segments I-VII usually with one or two pairs of exsertile vesicles. Stylets present on sternites II-IX and usually on some of the thoracic coxae. Thorax generally well arched and not flattened. Body always scaled. *Machilidae*

Compound eyes small or absent. Abdomen usually with some stylets and exsertile vesicles. Thoracic coxal stylets absent. Body much flattened and fish-shaped, or elongate and parallel-sided. Body scaled or not. *Lepismatidae*

Bristle-tails or rock-jumpers are rare in Australia, but in many parts of the world they are to be found in large numbers. Such is the case along the coasts of Europe, where they frequent the sandstone cliffs. In other parts they can be found on and under stones on hilly woodsides, as on the lower slopes of Table Mountain, South Africa. Little is known of their food, but it apparently consists of minute algae growing upon the rocks where they are found.

These insects are moderately large, measuring up to three-fourths of an inch in body length, fish-shaped and of a brownish colour which often shows remarkable reflections as the light falls upon the scaling. They are furnished with two long filamentous antennae composed of from 30 to 40 segments, each of which may be subdivided into 10 to 14 small parts. Compound eyes are always present, generally of large size and touching each other in the medial line for more or less of their length. Below the compound eyes lies a pair of large ocelli of peculiar form, often being dumbbell-like or triangular with the broadest part near the middle line. More anterior still is a simple organ which is spoken of as the *single ocellus.*

In the head the epicranial suture can frequently be seen, and the labrum and clypeus are well developed. The mouth parts themselves are exserted and conform to the primitive type as exhibited in the more generalised of the higher insects such as the cockroaches. The mandibles are simple in form, consisting of a single sclerite furnished with a well-developed molar plate and several apical teeth. These latter are often much worn by use and are renewed at each ecdysis. In general the mandibles show much similarity to the corresponding organs in some of the higher Crustacea. The superlinguae are well developed, each organ consisting of two lobes and a vestigial palp. The maxillae are conspicuous organs having a toothed lacinia and a hood-like galea and are furnished with a 7-segmented palp. In the male sex the first and second segments often exhibit specialised sensory organs. The labium or lower lip has a broad mentum and submentum, a paired prementum and a 3-segmented palp. Both glossae and paraglossae are present, each being divided into lobes. The terminal segment of the labial palp is supplied apically with sensory setae.

The thorax is comparatively large and considerably convex dorsally, sometimes being even gibbous. The coxal segments of the legs are large, and often the second and third pairs carry movable stylets, which have been correlated by some authorities with the exopodites of crustacean limbs. The tarsi are 3-segmented, ending in paired claws and sometimes having ventral scopulae of hairs.

The abdomen has eleven segments, the last ending in the long tail filament, while the penultimate segment carries the paired cerci. On some of the sternites are one or two pairs of exsertile vesicles, and also a pair of stylets. The median sclerite of the sternites may be large and triangular or more or less completely hidden by the coxal plates.

The genitalia are simple, usually consisting of one or two pairs of gonapophyses which, in the female sex, form the valves of a long ovipositor, and in the male are short and accompanied by a short median penis.

Of the life-history of these insects little is known except in the European genus *Petrobius*. In this there are at least six instars, each of which closely resembles the adult except in size. The first two instars, however, are entirely scaleless and without the thoracic coxal stylets of the later stages. There also appears to be a subimaginal instar in which the genitalia are developed but sexual maturation is not attained.

Classification of the Machilidae

The following three subfamilies are recognised, of which the first only is as yet known to occur in Australia:—

1. Abdominal segments all with median sternal sclerites almost if not quite invisible. At most each abdominal sternite with only a single pair of exsertile vesicles. *Meinertellinae*

   Abdominal segments II-VII with relatively large and visible triangular median sternal sclerites. 2

2. Only a single pair of exsertile vesicles on any one segment. *Praemachilinae*

   Some sternites with two pairs of exsertile vesicles. *Machilinae*

Subfamily MEINERTELLINAE

Two genera only, *Allomachilis* Silv. and *Machiloides* Silv. (= *Nesomachilis* Till.) are, so far, known to occur in Australia, while but a single representative of the latter is found in New Zealand. Careful search in the kinds of localities indicated above may reveal other genera and species, and for this reason the following key to the known genera of *Machilidae* is given:—

1. Exsertile vesicles present on sternites I-VII. 2
   Exsertile vesicles only on sternites II-IV. Legs II and III with coxal stylets. Paired ocelli triangular. Gen. *Allomachilis* Silv.
2. Coxal stylets on legs II and III. Paired ocelli transverse, elongate. Second segment of maxillary palp in male with subapical process and sensory setae or rods. Gen. *Machiloides* Silv. (= *Nesomachilis* Till.)
   Coxal stylets only on leg III or wanting. 3
3. Coxal stylets on leg III. 4
   Coxal stylets wanting on all legs. 6
4. Eyes large, much deeper than wide. Cerci slightly longer than body. Subapical process of palp II of male not hook-like Gen. *Megalopsobius* Silv.
   Eyes normal, wider than deep. 5
5. Coxal stylets on leg III reduced. Male gonapophyses absent. Gen. *Hypomachiloides* Silv.
   Coxal stylets on leg III normal. Gen. *Machilontus* Silv.
6. Male sex without tarsal scopulae. 8
   Male sex with dense tarsal scopulae. 7
7. Tarsal scopulae present in both sexes. Gen. *Meinertellus* Silv.
   Tarsal scopulae confined to the male. Gen. *Meinertelloides* Wom.
8. Paired ocelli not elongate, subrotund and almost touching lower margin of eyes. Gen. *Machilinus* Silv.
   Paired ocelli transverse. 9
9. Eyes large, deeper than wide. Paired ocelli transversely oblique. Median sternal sclerites almost invisible. Gen. *Macropsontus* Silv.
   Eyes normal. Median sternal sclerites visible. Male gonapophyses present or not. Gen. *Machilellus* Silv.

Genus ALLOMACHILIS Silv., 1904

Allomachilis froggatti Silv., 1904

Hitherto, this species was the only one recorded from Australia. It was described in 1904 by Prof. F. Silvestri from specimens collected by the late Mr. W. W. Froggatt on the coast of New South Wales. All the original specimens, however, were females.

Through the kindness of Prof. G. E. Nicholls the writer was able, while working at the University of Western Australia, in 1930, to examine about a dozen specimens of a Machilid collected by Prof. Nicholls and Mr. K. C. Richardson at Herring Cove, Two-people Bay, near Albany, Western Australia, in January, 1925. This material was labelled provisionally, "*Allomachilis*, sp. nov.," and again all the specimens were females. On re-examination it was possible to definitely identify the specimens with Silvestri's *A. froggatti*.

While holidaying in the Albany district in January, 1932, an attempt was made, with the aid of a friend acquainted with the district, to locate the spot where Prof. Nicholls had obtained his specimens, in the hope of finding the unknown male.

The habitat was found to be a small sandstone outcrop on the eastern end of Herring Cove; all the rest of the coast thereabouts being granite. About half a dozen specimens were seen, but owing to their extreme agility only two were captured. Of these, one was lost on the way back to Perth, but the other, on examination, proved to be a fully developed male. The following description of this sex deals mainly with the points in which it differs from Silvestri's description of the female:—

Description of Male—Dimensions, eyes, paired ocelli, antennae, thoracic and abdominal stylets and exsertile vesicles as in the female. Second segment of maxillary palpi simple and without sensory organs. Penis short; gonapophyses wanting.

Locality—Herring Cove, Two-people Bay, Western Australia, in January, 1932.

Remarks—This species also occurs in South Australia, where it has been found by the writer at Marino Rocks and at Yvonne Bay, Kangaroo Island. It has also been collected on Flinders Island, Bass Strait, Tasmania, by Mr. J. W. Evans.

Genus MACHILOIDES Silv.

= *Nesomachilis* Tillyard, 1924

In 1924 the late Dr. R. J. Tillyard erected the genus *Nesomachilis* for a New Zealand species, *N. maoricus.* In his description and figures there appears to be no characters by which the genus can be separated from *Machiloides* of Silvestri. That this is so has been confirmed by the writer, who, through the courtesy of Dr. J. Millar, of the Cawthron Institute, Nelson, New Zealand, has been able to re-examine Tillyard's type material, as well as fresh material from Nelson, kindly supplied by Mr. J. W. Evans.

About 1934 Dr. Tillyard informed me that he was making a biological study of a species of Machilid which he had obtained from the neighbourhood of Brisbane. Upon request he kindly sent a number of specimens for specific determination. Study of this material showed that, while closely allied to the New Zealand form, it belonged to a new and distinct species.

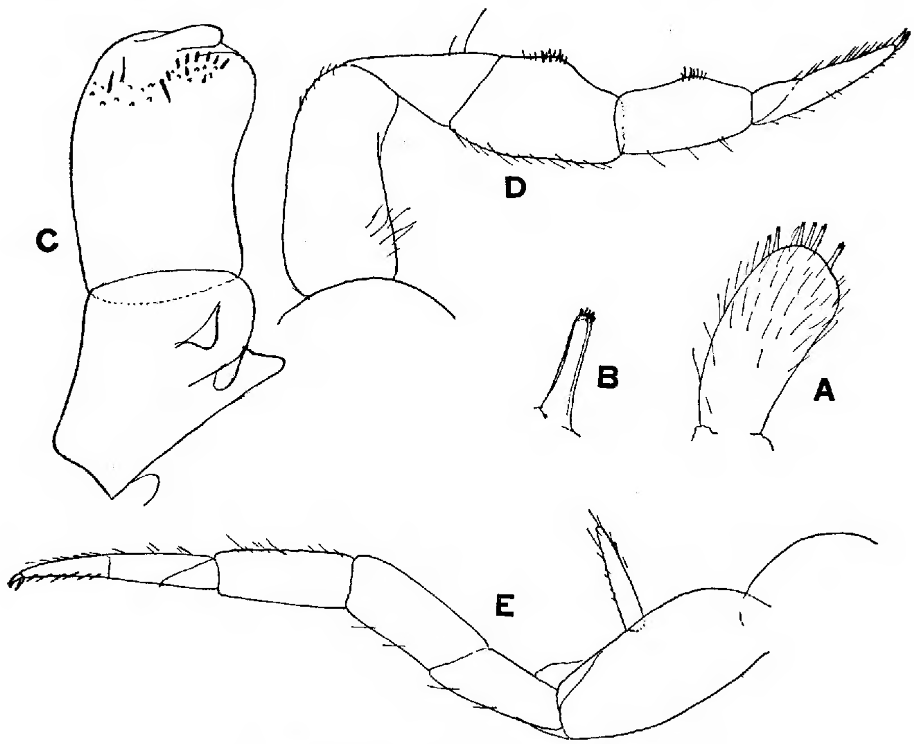
In the collections of the South Australian Museum was a single carded Machilid labelled "Stanwell Park, New South Wales," which had possibly been collected by A. M. Lea many years ago. On dismounting and dissecting, this specimen was found to be a female of the Brisbane species. Two other females, collected by Miss M. E. Fuller at Sydney in 1933, are also of the same form.

Description of the new species is as follows:—

Machiloides australicus n. sp.

(Text fig. A-E)

Length of body to 7 mm. Colour in spirit brownish, in life probably dark fuscous. Antennae thin, except the basal segments, reaching to two-thirds length of body; basal segment twice as long as broad, distal segments with 9-10 subdivisions. Eyes large, round, touching medially for two-thirds of their depth. Paired ocelli pear-shaped, transverse, widely separated medially. Labial palpi normal, apical segment with few but large setae or rods (fig. A-B). Maxillary



Machiloides australicus n. sp. (Male)
A, apical segment of labial palp; B, a single sensory seta from apex of above; C, first and second segment of maxillary palp; D, leg I; E, leg III.

palpi with the usual triangular and bulbous processes on segment I; II in the male with a subapical bent parallel-sided lobe, below which are a number of short, blunt, black rods; below these rods are some black-pointed setae which extend right across the segment. This structure somewhat resembles that described by Evans in 1927 for *M. maoricus* (Till.), but in the latter species the rods are placed in a distinct pocket formed by the subapical lobe and do not lie free as in the new species (fig. E). The remaining segments of the maxillary palpi are simple. The relative lengths of the segments of the maxillary palpi are:—male, 17 : 20 : 23 : 20 : 32 : 25 : 20; female, 10 : 15 : 13 : 13 : 20 : 15 : 15; lacinia shorter than galea. Mandibles normal with toothed apex and well developed molar plate.

Thorax moderately arched; legs I strong and somewhat raptorial, the femora and tibia being swollen inwardly, II and III longer and thinner with well developed stylets on coxae.

Abdominal segments with median sternal sclerites practically invisible, II-VII with a single pair of exsertile vesicles, II-IX with stylets, those on IX twice as long as those on VIII and with the apical seta two-thirds of their length. Median tail appendage two-thirds of body length, cerci rather shorter.

Male: penis short, gonapophyses absent.

Female: ovipositor short, annulated, scarcely reaching tip of ninth stylet.

The whole body is heavily scaled, the scales arranged in the manner described by Evans for *M. maoricus* (Till.).

Remarks—In the original description of *M. maoricus* the exsertile vesicles are given as present on sternites I-IX. This is a printer's error, for in no species of *Machilidae* so far known do these organs occur beyond sternite VII. The new species described above is a rare and apparently very local one. It appears to be an inland and not coastal form and should be searched for in stony woods.

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AN EXAMINATION OF THE BROWN COAL OF MOORLANDS
PART II

BY W. TERNENT COOKE

Summary

The results presented in this paper serve as an extension of the work on Moorlands coal previously &en in this journal (Trans. Roy. Soc. S. Aust., 1937, 61, 80).

Carbonization-Shaw (6) has made thorough carbonization tests with a charge of 97 lbs. of the coal, followed by an examination of the products. He used the apparatus of the Geological Survey of Victoria, following the procedure applied to the examination of the brown coals of that State.

AN EXAMINATION OF THE BROWN COAL OF MOORLANDS PART II

By W. Ternent Cooke, D.Sc., A.A.C.I.

[Read 11 November 1937]

The results presented in this paper serve as an extension of the work on Moorlands coal previously given in this journal (Trans. Roy. Soc. S. Aust., 1937, **61**, 80).

Carbonization—Shaw (6) has made thorough carbonization tests with a charge of 97 lbs. of the coal, followed by an examination of the products. He used the apparatus of the Geological Survey of Victoria, following the procedure applied to the examination of the brown coals of that State.

For the sake of comparison, tests have been made with the "Fischer" aluminium retort, an apparatus of semi-official status, using 50-gramme samples. The coal, as distilled, contained 16% moisture. Results are tabulated in Table I. During the tests samples of the gas were collected over varying intervals of temperature, and analysed for their content of carbon dioxide and sulphuretted hydrogen. The data relative to these gases have been combined and plotted as a curve. The large content of sulphuretted hydrogen is noteworthy, and suggests possibilities of recovering some of the sulphur content of the coal. Similar results have been obtained by Bone (7) with a sample of South Australian coal, doubtless from Moorlands.

The Char—The residue from the distillation is a finely divided black powder. Analyses gave carbon, 64·85%; hydrogen, 2·45%; ash, 24·30%. The ash contains 8·54% of sulphur as sulphate, equivalent to 2·08% of the 3·49% total sulphur content of the coal (with 16% moisture), leaving 1·41% "volatile" sulphur. The analysis then becomes: carbon, 64·85%; hydrogen, 2·45%; ash, 24·30%; sulphur, 1·41%. Difference (oxygen and nitrogen), 6·99%.

The ash of the char contains also 26·5% insoluble in acid, and 26·7% of iron, alumina, titania, besides the 8·54% of sulphate.

Nitrogen Content—A previously found value for nitrogen (1) is 0·4%. The author's sample gave 0·45% for the moisture-free coal. This low content is usual with lignites. Experiments showed that none of the nitrogen is extractable with dilute acid.

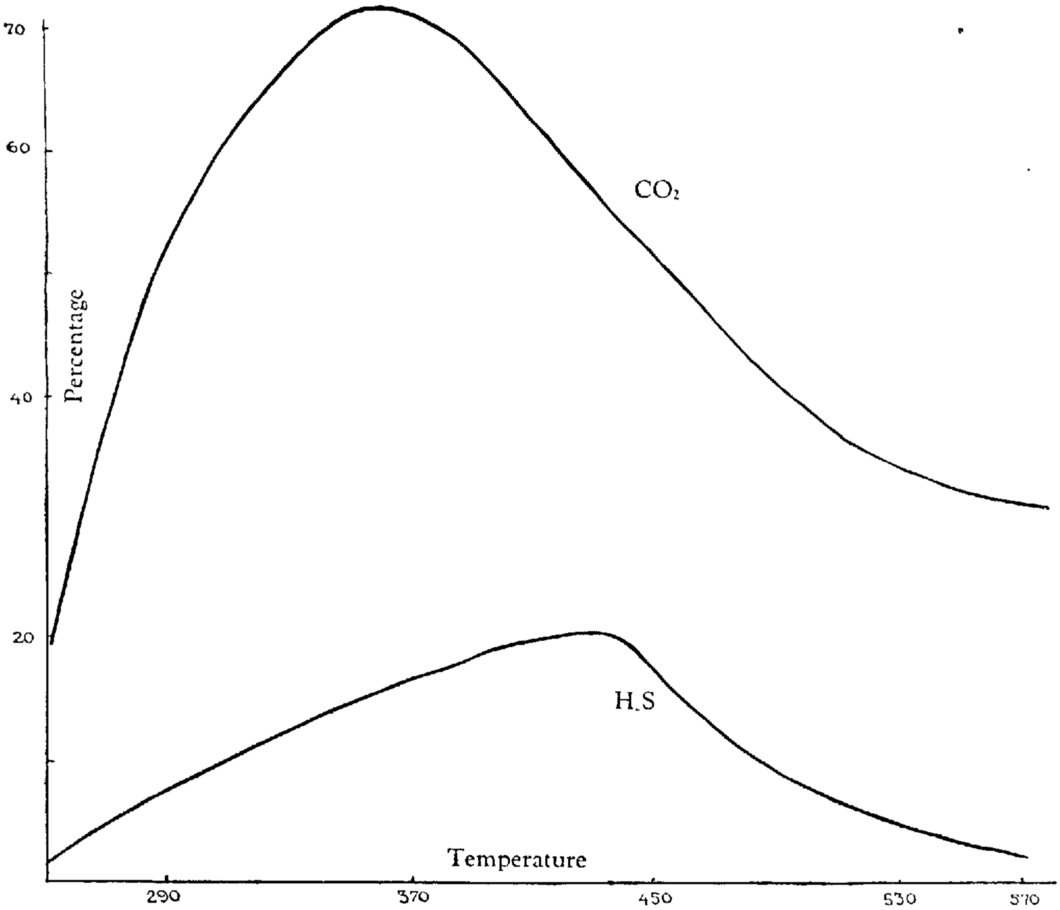
Chlorine Content—The percentage found for the bulk coal was 0·035%.

Carbonate Content—Calculated as CO_2, the value 0·2% was found.

Calorific Value—The official figure (2) given is 7,548 B.T.U. per pound. Taking the moisture content as given (2) 14·3%, one obtains 8,808 B.T.U. for the dry coal. Further, taking the value for sulphur 3·7% for moist, or 4·32% for dry coal, and applying Parr's formula, (3), the value 12,450 B.T.U. is obtained for "unit" coal. The corresponding values for Noarlunga (4), and Balaklava-Inkerman coal (5), are, respectively, 12,655 and 12,430.

True Mineral Content—King and others (8) have deduced a formula for arriving at an estimation of the true mineral content of a coal from a knowledge of the amount and composition of the "ash" and other analytical data. The values of certain factors in King's formula are based on a study of black coals, English mainly, but these factors should in general be applicable to brown coals. Thus the water content of the air dried shale associated with the black coal has an average value of 8%; the black clay found above the Moorlands clay has a water content of 6·1% (9). King's formula is:—

Mineral matter = 1·09% ash + 0·5% pyritic sulphur + 0·8% CO_2 + SO_3 in coal + 0·5% Cl − 1·1 SO_3 in ash.



Inserting the following percentage figures: 15·9% ash, 0·91% pyritic sulphur, 0·2% CO_2, 0·965% SO_3 in coal, 0·035% Cl, 2·81% SO_3 in ash, the final value 15·84% is obtained, almost identical with that of the "ash."

Erdmann and Dolch also have given a formula for calculating the true mineral content (10). This formula gives a value of 15·6%, which again differs but slightly from that of the "ash."

King has also given formulæ for calculating the composition of the actual coal substance, i.e., on the moisture and ash-free basis. Using the values already found for the bulk sample (9), the calculated composition is carbon, 65·49%; hydrogen, 4·80%; nitrogen, 0·53%; sulphur, 3·45%; oxygen, 25·73%.

Effect of Moderate Preheating on the Coal—It is known that a slight improvement in the quality of a lignite can be effected by heating to a temperature short of active decomposition; some combined oxygen is driven off as water and carbon dioxide. The effect was studied by heating portions of air-dried coal, containing about 13% of moisture, in a stream of dry, oxygen-free nitrogen. Heating was in two stages, first to about 120° C., and then to about 230° C.; the water and carbon dioxide formed over each temperature interval were collected and weighed, and the loss in weight of the coal found. Over the lower interval the loss is almost entirely hygroscopic water; over the higher, the carbon dioxide is about one-half of the water. There is no appreciable amount of other volatile products, as shown by the concordance between the sum of the weights of the collected products and the loss in weight of the coal. Taking the average figures of three typical experiments, the weights of volatile products over the two ranges of temperature are, respectively:—carbon dioxide, 0·4% and 1·8%; water, 13·3% and 3·2%, giving a total of 18·7%, of which 5% is evolved after loss of hygroscopic water. The total loss in weight of the coal was also 18·7%. At about 230° C. there is evidence of the beginning of more pronounced decomposition—the characteristic smell of heated brown coal is noticeable. The preheated product has the composition:—C. 56·70%, H. 4·02%, O. 18·12%, S. 4·32%, and ash 16·84%. That a slight improvement has been effected is shown by a comparison of the composition of the preheated with that of the original coal, both calculated on an ash and moisture-free basis (original coal in brackets):—C. 68·19% (65·55%), H. 4·83% (4·98%), O. 21·79% (24·60%), S. 5·19% (4·87%).

TABLE I.

Final Temp. C.	AS DISTILLED, 16% Moisture				ON DRY BASIS	
	Liquor	Tar	Char	Diff.	Tar	Char
550	23	6·6	53·2	17·2	7·85	63·3
550	21·8	7·0	54·2	17·0	8·4	64·5
520	22·6	6·2	57·8	13·4	7·4	68·8
500*					8·78	55·06

* Shaw, "Mining Review," 37, 75

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CONTRIBUTIONS TO THE ORCHIDOLOGY OF AUSTRALIA

BY R. S. ROGERS

Summary

A small erect and rather slender species, about 4-8 cn~.h igh. Leaf linearlanceolate, slightly hairy, usually as long or sometimes much longer than the inflorescence, strongly 3-nerved with numerous smaller veins. Stem hairy, an acute linear slender bract, about 1 cm near the middle. Flower relatively large, solitary, yellowish, with dark reddish-brown veinings, about 2.5 cm. in diameter, on a short slender pedicel subtended by a subulate bract about 1 cm. long. Segments of perianth similar, about 1-5 cm. long, yellowish with longitudinal reddish brown median nerve, tapering to a filamentous conspicuously clavate point, dorsal sepal incurved over column, lateral sepals porrect, lateral petals erect or semipatent.

CONTRIBUTIONS TO THE ORCHIDOLOGY OF AUSTRALIA

By R. S. Rogers, M.A., M.D., D.Sc., F.L.S. (Lond.)

[Read 14 April 1938]

Caladenia sigmoidea n. sp.

Species terrestris, pusilla, circa 4-8 cm. alta. Folium fere aequans vel inflorescentiam aliquanto excedens, anguste lanceolatum, leviter hirsutum, vale 3-nervia cum venis minoribus numerosis. Caulis hirsutus, ad medium bractea acuta gracilis circa 1 cm. longa. Flos solitarius, subflavus in diametro circa 2·5 cm.; pedicellus brevis; segmenta similia, aequalia, circa 1·5 cm. longa, angusta, subflava, filamentosa, conspicue clavata, lineis badiis ornata, sepalo dorsali incurvato, lateralibus porrectis, petalis erectis. Labellum mobile, unguiculatum, sigmoideum, subflavum; explanatum subanguste-ovatum, marginibus paene integris, apice obtuse uncinato; lamina cum venis atrobadiis divergentibus ornata; calli carnosi, atropurpurei, biseriati. Columna elongata, gracilis, alata, apice leviter incurvata; anthera obtusissima; stigma semilunare, sub anthera. Anthera obtusa.

A small erect and rather slender species, about 4-8 cm. high. Leaf linear-lanceolate, slightly hairy, usually as long or sometimes much longer than the inflorescence, strongly 3-nerved with numerous smaller veins. Stem hairy, an acute linear slender bract, about 1 cm. near the middle. Flower relatively large, solitary, yellowish, with dark reddish-brown veinings, about 2·5 cm. in diameter, on a short slender pedicel subtended by a subulate bract about 1 cm. long. Segments of perianth similar, about 1·5 cm. long, yellowish with longitudinal reddish-brown median nerve, tapering to a filamentous conspicuously clavate point, dorsal sepal incurved over column, lateral sepals porrect, lateral petals erect or semi-patent. Labellum mobile on a distinct claw, sigmoid, yellowish, somewhat narrowly ovate when spread out with dark red veinings, margins entire or often bidentate on each side, the tip obtusely uncinate; lamina traversed by dark red divergent and longitudinal veins, and provided in its proximal half with two parallel median rows of dark reddish fleshy calli. Column winged, elongated, slightly incurved at the apex. Anther quite blunt. Stigma semilunar just below the anther. Anther obtuse.

Locality—Western Australia, Kumarl, 25 August 1937.

I am indebted for this very interesting and distinctive species to Col. B. T. Goadby, who informs me that it was collected by an observant teacher, Mr. Horbury, at the above locality near Salmon Gums, on the Kalgoorlie-Esperance Railway line.

Pterostylis Mitchellii Lindl.

Locality—Western Australia. Collected by Mr. Horbury at Kumarl and forwarded by Col. Goadby. New to the Western State.

PTEROSTYLIS PUSILLA Rogers

Locality—Western Australia. Collected by Mr. Horbury at Kumarl and forwarded by Col. Goadby. New to the Western State.

PTEROSTYLIS MUTICA R. Br.

Locality—Western Australia. Forwarded by Col. Goadby. Collected by Mr. Horbury at Kumarl, 24 August 1937.

Thelymitra Dedmanae sp. nov.

Planta robustiuscula, terrestris, alta 20-40 cm. Folium glabrum, ellipticum vel oblongo-ellipticum, papyraceum, multistriatum, ad basin contractum, circa 12 cm. longum, 1·5-3 cm. latum in meis speciminibus. Caulis glaber, bracteae elongatae, acutissimae, 2 vel 3. Flores 3-6, pedicelli graciles circa 6 m.m. longae, majusculi, 3·5-4 cm. in diametro, ordorati, chasmogami. Segmenta perianthii patentia, badia fere iridescentia, non maculata; sepala acuta circa 2 cm. longa circa 8 mm. lata, multistriata; petala sepalis breviora angustioraque, inferiori segmentis ceteris multo breviore angustioreque apice truncata marginibus integris. Columna circa 1 cm. longa, late alata, rubri-aurantiaca, processu clavato dorsali instructa; cucullus alte pectinatus, conspicue aurantiacus; anthera humilis, apice in processum digitaliformem producta; stigma subquadratum, rostellum in medio marginis superioris.

A rather robust terrestrial plant, about 20-40 cm. high. Leaf glabrous, elliptical or oblong-elliptical, multistriate, sheathing at the base, about 12 cm. long, 1·5-3 cm. wide in my specimens. Stem glabrous, its bracts elongated very acute, 2 or 3 in number. Flowers racemose, 3-6, pedicels slender about 6 mm. long, rather large, 3·5-4 cm. in diameter, sweet scented, opening freely. Perianth segments chestnut coloured almost iridescent, not spotted. Sepals acute, about 2 cm. long, 8 mm. wide, multistriate; petals shorter and narrower than the sepals, the lower are much shorter and narrower than the rest its apex truncate and margins entire. Column about 1 cm. long, widely winged, reddish-orange, with a clavate dorsal appendage; the hood deeply pectinate, conspicuously orange in colour; anther low and broad, its apex produced into a finger-like process; stigma subquadrate, with the rostellum in the middle of its upper margin.

A near relative of *T. fuscolutea*, R. Br., but with a narrower leaf, unspotted perianth-segments and very distinctive coloration of the flowers. It also shows structural differences in the flowers, a differentiated labellar petal and a somewhat different column.

Locality—Western Australia. Toodyay, 11 November 1934. Mrs. and Miss Dedman, in whose honour the plant has been named.

In general appearance, the plant is strikingly beautiful and worthy of cultivation.

ON THE OCCURRENCE OF A FOSSIL PENGUIN IN MIOCENE BEDS IN SOUTH AUSTRALIA

BY H. H. FINLAYSON

Summary

The specimen herein noticed was found by Mr. W. Burdett in the cliffs above Christie's Beach on the east shore of St. Vincent Gulf, at a point about 16 miles south of Adelaide, South Australia. The site has been examined by the late Professor Walter Howchin, who has pronounced the beds to be of undoubted Miocene age, and it is satisfactory that this, the first record of the tertiary Spheniscidae in Australia, should be free from the chronological uncertainties which attach to some other of the occurrences of the family elsewhere.

ON THE OCCURRENCE OF A FOSSIL PENGUIN IN MIOCENE BEDS IN SOUTH AUSTRALIA

By H. H. Finlayson

Plate I

[Read 14 April 1938]

The specimen herein noticed was found by Mr. W. Burdett in the cliffs above Christie's Beach on the east shore of St. Vincent Gulf, at a point about 16 miles south of Adelaide, South Australia. The site has been examined by the late Professor Walter Howchin, who has pronounced the beds to be of undoubted Miocene age, and it is satisfactory that this, the first record of the tertiary Spheniscidae in Australia, should be free from the chronological uncertainties which attach to some other of the occurrences of the family elsewhere.

The bone (pl. i, fig. A-B), which is a left humerus, is held in a friable matrix of calcareous grit. Originally only the proximal surface of the head and the outer surface of the shaft were exposed, but by careful flakeing with a steel point, all its margins have been satisfactorily developed without damage, except in the region of the sesamoid articulation at the distal extremity. Here the matrix proved harder than elsewhere and, as the bone was weakened by a transverse fracture, little pressure from a tool could be applied and some slight indefiniteness of outline has been allowed to persist.

The bone is in excellent preservation and is complete except for the tuberculum externum, which has been broken away anciently. The outer exposed layers of the cortex have become somewhat chalky by weathering, but the main mass of the shaft is strongly mineralized and has a dense flinty texture. Although the shaft shows four transverse fracture lines, there is no evidence of crushing or distortion.

In addition to the humerus, some fractured laminae probably derived from a radius, and another fragment showing a porous cancellated structure, are also present.

Lowe (1), in his excellent paper on the primitive characters of penguins, reviews the fossil humeri from Seymour Island, figured and described by Wiman (2), and singles out five structural characters, of functional significance, which distinguish the humeri of these and other tertiary penguins from those of recent species.[1] In describing the present specimen, therefore, it seems expedient to concentrate upon these points, rather than to embark on a detailed account of its morphology.

1. A more pronounced inturning of the articular surface of the head of the humerus, than in recent species, was claimed by Wiman. This was doubtfully conceded by Lowe, who considered that in the fossil birds it might be correlated with less freedom of rotary movement within the joint.

(1) With the partial exception of the primitive *Eudyptula*

In the present specimen the humeral head is somewhat abraded, the cancellated tissue being exposed, and its dimensions possibly somewhat reduced. Making full allowance for this, however, it still supports Wiman's claim. In a posterior view, the onsetting of the head to the shaft is appreciably more axial than in *Aptenodytes forsteri,* for example. In the present fossil the long axis of the shaft passes almost through the vertex in this aspect of the head, whereas in *A. forsteri* the vertex is displaced about 6° mesiad. (See pl. i, fig. B.)

2. The smaller size of the fossa pneumatica (f. subtrochanterica) in the tertiary species.

This is strikingly illustrated in the present bone, both as regards width and capacity, though some allowance must be made for attrition in the fossil. Moreover the cavity is simple, without or at most with slight indications of the secondary cavity on the internal wall, as in *Aptenodytes forsteri.* The total capacity of the fossa (as preserved) is just one quarter that of the cavity in a rather small *A. forsteri.*

3. In the tertiary humeri the trochlea ulnaris and trochlea radialis occupy sites upon the lower angle of the preaxial border, rather than upon the distal margin, and their articular surfaces face outwards rather than downwards as in the recent genera. This leads to the articulation of the antibrachium at a smaller angle with the humerus than in recent penguins. Lowe interprets this as evidence of inferior natatory specialization.

In the present fossil the facets of the two condyles are confluent, as in the humerus attributed by Hector (3), to *Palaeeudyptes antarcticus* Huxley (4), but the site of the conjoined surface is exactly as in Wiman's humerus No. 3, as refigured by Lowe *(loc. cit.).*

4. The preaxial border is without an angular prominence and the maximum width of the bone is towards the proximal rather than the distal extremity. Both conditions are clearly exhibited by the fossil.

5. Wiman *(loc. cit.)* suggested that in the Seymour Island humeri the entepicondylar process bearing the sesamoid grooves was less produced than in recent penguins. Lowe considered that the differences observable were due to abrasion of the fossils. But it is quite clear in Hector's figure of the Nelson (N.Z.) humerus, and somewhat less so in the present specimen, that the angle is much less prominent than in Lowe's hypothetical outline *(loc. cit.,* fig. 12a), or in the modern Aptenodytes, though it may find a parallel perhaps in other modern genera.

While possession of the above listed structural features satisfactorily allies the South Australian fossil with others of like geological age from widely sundered localities in the Southern Hemisphere, the question of generic identification remains a difficult one; partly owing to the impossibility of instituting comparisons with forms founded on bones other than humeri, but still more to the uncertainties which, in the Spheniscidae, surround the diagnostic value of the bone.

The activities of Ameghino, Moreno, Mercerat, and Wiman *(loc. cit.)* have greatly expanded the list of names of fossil penguins, so that it now includes

35 species referred to 22 genera (5-6). The form which is geographically nearest to the site of the present find is that which was first described, *Palaeeudyptes antarcticus* Huxley, 1859 *(loc. cit.)*, from beds of similar age in New Zealand. Huxley founded the species on a tarsometatarsus only, but in 1871 Hector obtained other bones from the same horizon as the first find, which he ascribed to the same species. The second find included an almost perfect humerus, which is excellently figured *(loc. cit.)* pl. viii, figs. 1 : 2 : 3). Comparison of the South Australian specimen with this figure reveals a very close correspondence both in dimensions and structural detail, and the few points of difference are of such kind as to be readily accounted for by differing age of the individual birds, and varying degrees of erosion of the fossils, which is considerably greater in the South Australian specimen.

While such an agreement in macroscopical features might be regarded as a valid identification in Palaeontology, it cannot be overlooked that in the present case there are other considerations, both morphological and zoogeographical, which introduce an element of doubt, and these may be briefly noted.

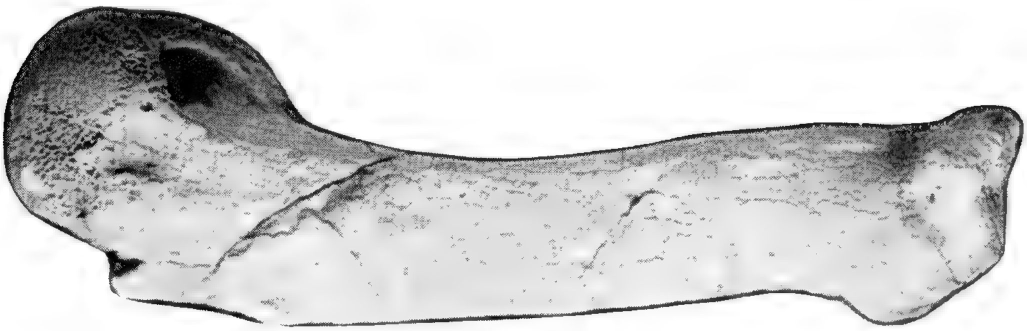
1. While the tertiary genera may be satisfactorily distinguished from the recent by osteological characters, contemporary recent genera show amongst themselves a much smaller range of diversity in such structural points. Both Watson (7) and Pycraft (8) have unequivocally stated that in some recent genera, which are markedly distinct in external characters and habits, the humeri may be virtually identical. A similar state of things in the tertiary forms, while less probable perhaps, is still possible, and the birds which became fossilized at Nelson and Christie's Beach, respectively, may have shown much greater total differences than can now be found in their humeri.

2. The New Zealand and Australian finds are located in zoological subregions of marked and long-established distinctness; a distinctness exemplified by a very large proportion of both the fossil and recent avifauna of the two.

In the existing penguins, the pelagic habit has been so perfected that voyages of many hundreds of miles are annually made by the migratory species, and on occasion these normal distances are enormously exceeded, as is shown by the records of extralimital occurrences of several species, and the accounts of eyewitnesses who have observed the birds in the open oceans (9).

Obviously the existence of such pelagic habits in the tertiary penguins would tend to nullify the zoogeographical distinction by providing the means (though not necessarily the incentive) for transgressing the boundaries of the two subregions.

3. However, in the case of the tertiary penguins of the Antarctic Archipelago, which lived under temperate or even subtropical climatic conditions, Lowe considers there is evidence in the tarsometatarsus and humerus of superior terrestrial and inferior aquatic specialization, respectively. This suggests the probability that a comparatively sedentary coast-frequenting habit then prevailed (which has persisted to some extent in one existing species of *Aptenodytes)*, and that the truly pelagic, deep sea-going habit of some of the modern species was a much later accomplishment, acquired in response to increasing severity of climatic



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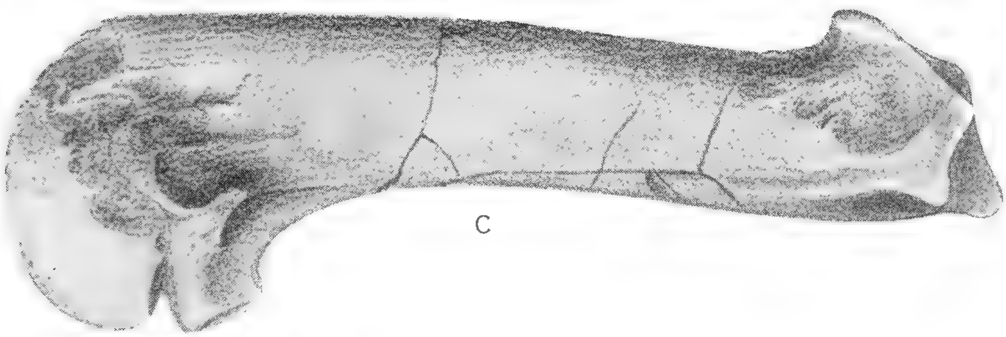

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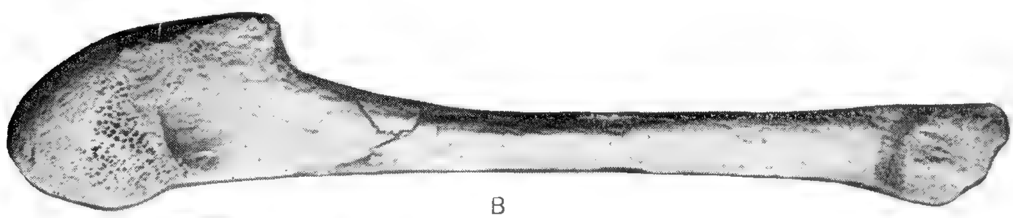

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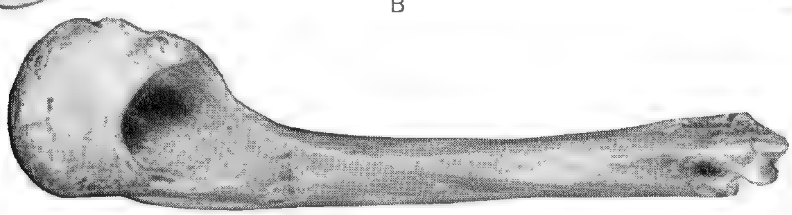

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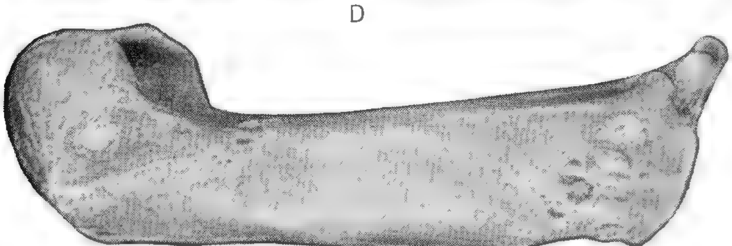

E

Photo, H. H. Finlayson

conditions imposed by later glaciation. In this connection, it is significant that in several existing species it is only the more southerly colonies which undergo an annual migration.

4. That all conclusions as to relationship drawn from such considerations as are set out in (2-3) are fallible, unless the original centre of dispersal of the forms is known, seems to be indicated by the presence of *Eudyptula minor* in both New Zealand and South Australian waters; *Eudyptula* being the most primitive of the existing genera, and that which in its coast-wise and relatively sedentary habit seems least adapted to bridge the gap between the two areas.

In view of the uncertainty in the value of the evidence derived from the humerus and the conflict in the theoretical considerations bearing on distribution, I have not felt justified in applying a name to the fossil. As the chief object of the present note is to record the occurrence, it will suffice to point out again its apparently close relation to *Palaeeudyptes antarcticus* Hux.

In conclusion I have to thank Mr. W. Burdett for an indefinite loan of the fossil for purposes of description; and Messrs. J. Sutton and H. Condon, of the Department of Ornithology of the South Australian Museum, who have made available material for comparison and assisted in other ways; and the authorities of the Public Library of Melbourne, and the Australian Museum, Sydney, for timely loan of books.

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EXPLANATION OF PLATE I

Fig. A. Left humerus of a penguin from Miocene beds of Christie's Beach, South Australia. Lateral (external) aspect. x 0·81.

Fig. B. Ditto. Postaxial view. x 0·81.

Fig. C. Right humerus of a penguin from the Miocene of Nelson, New Zealand. Lateral aspect (after Hector, Trans. and Proc. New Zealand Inst., 1871, pl. xviii, fig. 1). x 0·71.

Fig. D. Left humerus of *Aptenodytes forsteri*. Posterior view. x 0·71.

Fig. E. Ditto. Lateral view. x 0·69.

PRUPE AND KOROMARANGE
A LEGEND OF THE TANGANEKALD, COORONG, SOUTH AUSTRALIA

BY NORMAN B. TINDALE

Summary

The traditions and beliefs of the Tangane people of the Coorong, in South Australia, seem to belong to several cultural strata. Some stories relate to the behaviour and adventures of heroic ancestral beings "who made the country, and prepared it for the present natives." Such beliefs may deal with the life-story of Ngurunderi ['njurunderi] and other superhuman man-like beings, collectively called ['maldawuli]. Other stories are centred around the behaviour of numerous [qaitje] or totemic beings, most of whom are considered to be birds *(e.g.,* crow, eagle, silver gull, pelican), although when the events of the stories are taking place they usually are manifesting more of their human attributes than of their bird-like ones. A further stratum of stories relates to individuals of unequivocably human origin, who possess [njaitje] like present-day folk and about whom there is no suggestion of an alternative or subsequent translation into the [njaitje] form.

PRUPE AND KOROMARANGE

A LEGEND OF THE TANGANEKALD, COORONG, SOUTH AUSTRALIA

By NORMAN B. TINDALE, B.Sc.

[Read 14 April 1938]

PLATE II

The traditions and beliefs of the Tangane people of the Coorong, in South Australia, seem to belong to several cultural strata. Some stories relate to the behaviour and adventures of heroic ancestral beings "who made the country, and prepared it for the present natives." Such beliefs may deal with the life-story of Ngurunderi [ˈŋurunderi] and other superhuman man-like beings, collectively called [ˈmaldawuli]. Other stories are centred around the behaviour of numerous [ŋaitje] or totemic beings, most of whom are considered to be birds *(e.g.,* crow, eagle, silver gull, pelican), although when the events of the stories are taking place they usually are manifesting more of their human attributes than of their bird-like ones. A further stratum of stories relates to individuals of unequivocably human origin, who possess [ŋaitje] like present-day folk and about whom there is no suggestion of an alternative or subsequent translation into the [ŋaitje] form.

The Prupe story belongs to the last-named category. Its elements are simple:—

Cannibalistic behaviour of an aged blind woman.
The good grandmother and her bad sister.
Exchange of feeble eyes for good.
The leaking vessel which she strives to fill.
Destruction of the bad woman and her camp by a sudden catastrophe.

The site of the present story is connected with a strange circular depression about thirty metres in diameter and ten deep, of unexplained origin, situated near McGrath Flat homestead, on Section 24, Hundred of Glyde.

According to one suggestion this may be a meteorite crater; its form being such as to encourage this view. However, there is no evidence of the presence of meteoric material on the surface near the supposed crater, and the suggestion cannot be accepted until confirmation is forthcoming; nevertheless, definite association exists between such a depression and a story of a catastrophic event accompanied by a blaze of fire. It seems possible that the story, in its present form, may be the dramatisation of an actual meteorite fall at this spot.

The story was obtained by the writer several years ago, and the phonetic rendering of the vowels is somewhat broader than in more recent work.

The phonetic system employed is that adopted at the University of Adelaide and described by the writer in 1935.

Differences between the series n d t, and the interdentals, **n d t,** are well marked in this language. In the text the sounds of the second series are denoted by black letter type, while on the sketch map they are indicated by a vertical black line under the letter. In the interdental series the sounds are made with the tongue protruding about 0·5 centimetre between the teeth.

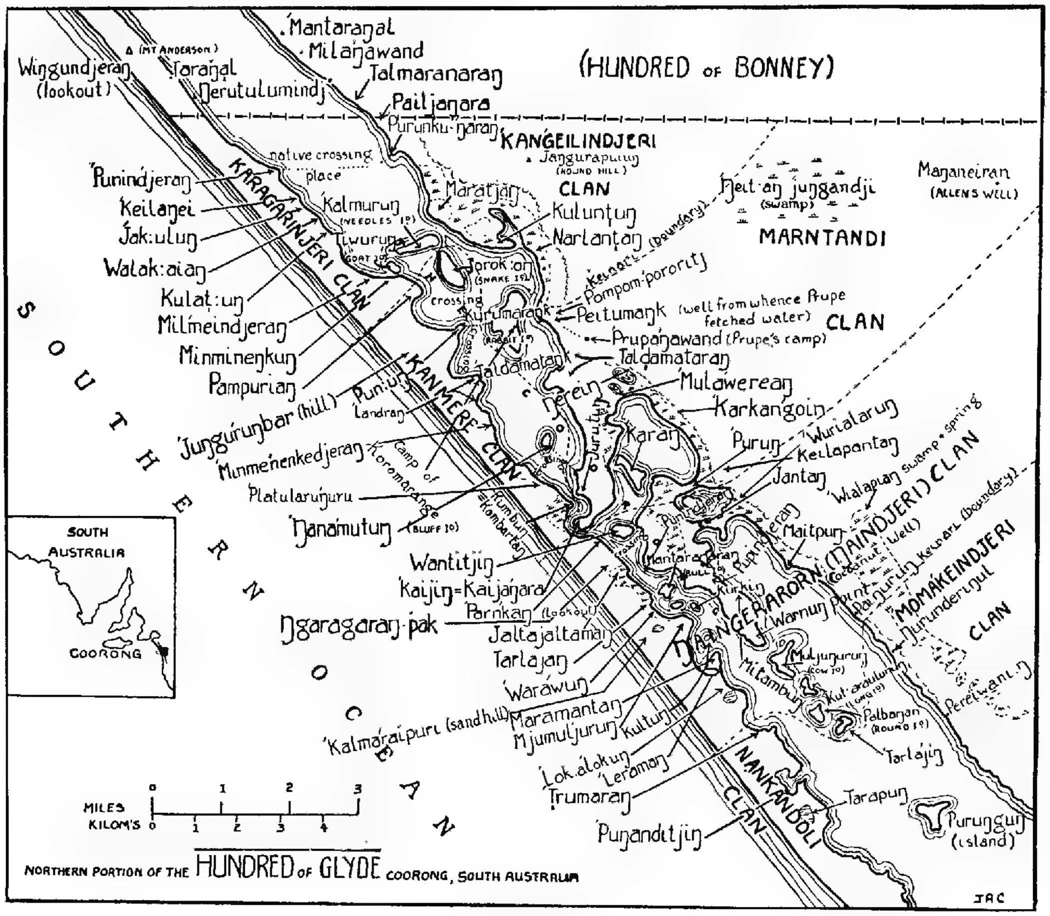

Fig. 1

This feature has been noticed previously by the writer in Jaraldekald texts (1937), and since by Miss McConnell among the peoples of Cape Yorke Peninsula, and by Capell (1937) among the Kurnu.

The following short story is the first Tanganekald prose text to be published; some songs were given, however, in a recent paper (Tindale, 1937). Prose texts in several other languages of the South-East of South Australia await collation and publication.

The earliest indication of any element of this story seems to be the bare mention in Meyer's Raminjeri vocabulary (1843, p. 57) that *brupe* means "bad or old"; the present story gives a fuller meaning to the word.

In several places the translations suggested by the informant do not give the exact sense. With larger vocabularies and a more detailed gathering of details of grammar, etc., this may be remedied. Where an informant has almost ceased to use his own language, owing to lack of fellows, it is not surprising when he finds difficulty in explaining his meaning in a foreign tongue, even when it has been known to him since early manhood.

The accompanying figure (pl. ii) shows Milerum, narrator of the legend drinking from a human skull vessel ['merikin] similar to the one used by the old woman of this story. Such vessels are made waterproof by being plastered with a mixture of red ochre and oil of the emu or whale.

A sketch map shows the northern half of the Hundred of Glyde and records the positions of places mentioned in this story. Upon it are also inscribed the names of all other known native place-names in the area, together with some Tangane ['keinari] or clan boundaries. This sketch map is a portion of one of the many "hundred" maps covering the South-East of South Australia, upon which have been marked about 1,500 significant native place-names of the Tanganekald and adjoining tribes. When published in full they will give a comprehensive idea of the nomenclature and geographical knowledge of members of a typical South Australian tribe. The names are of necessity crowded, but if they are studied in conjunction with the Hundred map, a close approximation to the location will be obtained.

When recording this information in the field informants frequently had cause to lament the physiographic changes which have been wrought by the clearing of sandy ground, the stocking of the Coorong with sheep and cattle, and its invasion by rabbits, leading to rapid drifting and alteration of old fixed sandhills, lookouts and other landmarks. As one old man expressed it: "Our [*'maldawuli*] told us, long, long ago, to 'beware of ants.' White men must be the 'ants' he spoke of, for they have eaten away all my people, my herbs, my game, and even my sandhills."

The Coorong is an example, on a gigantic scale, of a lagoon locked behind an offshore bar which extends from Port Elliot in the north to beyond Kingston in the south, a distance of well over one hundred and forty miles. This bar and lagoon was preceded by an earlier one, the remains of which form the landward shore of the present-day Coorong lagoon. This older dune series, the Woakwine Terrace, was preceded by similar still earlier physiographic features, which dominate the country further inland in alternating belts of dune and swale, for as much as sixty miles.

The second sketch map gives a generalised view of a portion of the Coorong to illustrate six descriptive terms used by Tanganekald people.

To Tangane folk the grass-covered sandy limestone slopes of the Woakwine Terrace, forming the landward shore of the Coorong, were known as ['teŋgi]. Along this strip were many favourite camping places, all of them exposed in some degree to the attacks of strangers from out of the inland scrub. Inland from ['teŋgi] was ['lerami], mile upon mile of mallee and swampland, fit only for hunting. ['Lerami] was literally the "back country".

The shallow Coorong lagoon itself was ['pandalapi], source of the fish which formed the staple food of their economic system. ['Pariŋari], the seaward shore of the lagoon provided the ideal home of the Tangane. Here, with their backs to the ocean, a high fixed dune to serve as lookout and a clear view in the

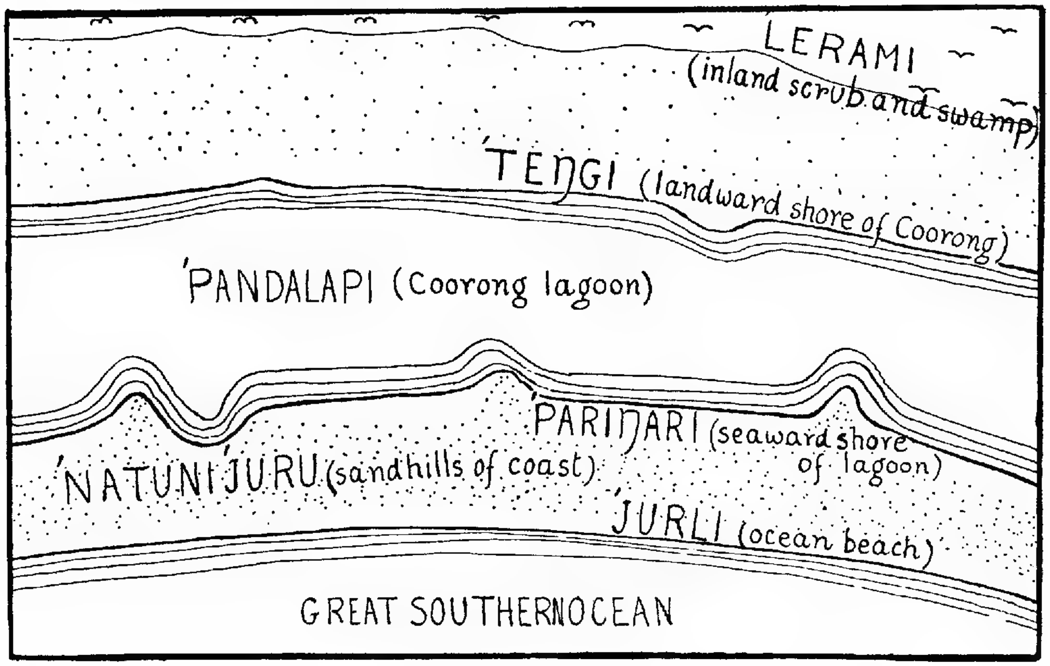

Fig. 2

landward direction, they felt safe from their enemies. Behind them was ['natuni'juru], a continuous belt of dunes, from one to three miles wide and a hundred miles long, separating them from ['jurli], the ocean beach. In the season their womenfolk repaired daily to ['jurli] to gather cockles, the *Donax deltoides* whose remains today are strewn thickly on every foot of old dune from Middleton to Kingston.

These native terms appear so often in Tangane description and conversation that it is desirable that they should be on record. Lerami, Tengi, and other terms are so euphonious, and supply such a want that they might well be used by the geographer and physiographer as names for these outstandingly interesting features of the South-East of our State.

'Prupe and 'Koro'ma'range

'Nunap 'pan:a 'njerei 'nentara 'jamp 'prupuna('w)ante 'peker'at
[Koro'ma'range] [1] scared was Prupe a-meal

kurupula al'porula. Wenjatananam 'marok'eianam 'marmar.
eat baby To-her took-to-her fish-(presents of).

'Nun':uk 'telianu 'puntunu 'wanjal 'naŋgi im'pakabali.
She [Prupe] idea-had sneak-down spy on grandmother-true [*i.e.*,K.].

Aŋgalamp [2] 'wanjal 'plap:ai inaŋg rainurumuŋg. 'Weniaŋg parlu
Belonging to me spy on inside-"heart" I feel. Come down this time
stomach

ŋgarelaŋgul 'kunduŋg 'kaiparl [3] ':aŋgal i'nal jal lal 'koŋgodapaitj.
she had gone find fishing gone while out.

Kan'deile [4] kuŋu inal 'ŋgeiral wenjil naŋg peinpun 'pareŋguki. 'Mekan 'ŋgeir
Gone in fish crying drink water for. What cry for.

'maraparik 'pakanu. 'Wenjata'naŋg 'peinpu 'weinjal 'mutung 'kaijerep-
[said sister] grandmother. To her drink gave drunk it was

':ung 'pulu'wuntu 'wenjatan 'lam:aŋg 'waldarap 'kaltaŋguru 'kapuntu
satisfied slung her over shoulders carry went away very fast

'talda'mading. 'Malawaijap [5] 'leawu 'kuiŋgu 'jeŋgura enapu 'pulteina'pun.
home arrived. Soon after not very long

'Onkanap 'pelalamp. 'Keiandu 'puntai ip':ak:a 'pali. 'Pareŋgu
to take (want to) eyes good. Arrived [then] grandmother good [K.]. Water

'kan:an 'pakanu ma! 'ŋginteil [6] 'palal 'paka 'baluntu inaŋ
get me grandmother go! You go grandmother other [P.] with

'merikin. 'Wada jau 'belinjeri 'ŋgapun 'jurukulai. [7] 'Wanja
skull-dipper. Went smartly walking to bale out [K.] Then

'ŋgara ŋgaratun kaljai 'anta:anja pereokuŋgar. Nunanil winmaŋguru wanjil
made snare false cry sound for water. Trick played on her then

'ŋgarakun 'nunai 'nelang 'pultuwapini 'toro'tuluwia [8] 'werukol ilŋgeril tumul
snare kicked (?) rushed out strangled [in snare]

'ŋgoro'toloni 'talajarinji 'enambil 'jaran ku'rambil. 'Wenjankol [9] 'wandandi-
kicked fire big blaze of fire. [K.] saw across

land 'ŋgakun 'Juŋgu'ruŋbar.
[Coorong] looking from Juŋguruŋbar [place].

Notes 1-9

1. Koromarange feared to allow Prupe to come down to her lest she find the child and eat it or exchange eyes with it.
2. Prupe noticed that K. had started to bring fish up to her; never done this before, she was suspicious. She said, "Once upon a time I used to go down to my sister."

3. On one occasion when Prupe went down K. rushed out of her hut to give her fish.
4. P. pretended that she was K. The word-for-word translation is here doubtful.
5. K. arrived soon after, as P. was preparing to exchange her bad eyes for those of the child.
6. K. pretended she was tired and sent P. for water. She pierced a hole in the human skull water-dish so that it would leak.
7. P. baled out water; the skull leaked; she dipped again and again, finally put her finger in the hole. While she was away K. made a snare to trap her. P found she had been tricked, rushed out of the hut; was snared.
8. P. kicked the fire, causing a great hole in the ground; she burnt herself to death. This place is now a large cavity in the ground to the north of the McGrath Flat homestead, on Section 24, Hundred of Glyde. The original text here was not completely translated.
9. K. fled across the Coorong with the child and watched the fire from the top of the sandhill called ['Juŋgu'ruŋ'bar.]

A General Rendering of the Story

Prupe and Koromarange were two Marntandi clan sisters who lived near McGrath Flat on [teŋgi], i.e., the landward shore of the Coorong. They had the same [ŋaitje] totem. One lived at a place just behind the present McGrath homestead, called [Prupa'ŋawand]; the narrator was first shown the place when he was a boy. It is a big hole in the ground. The other sister lived a mile away to the west along the Coorong, on Rabbit Island, at a place called ['Koro'maraŋ'gul] or ['Kuruma'raŋk].

At first Prupe had good eyesight, but she began to go blind and became a very savage person, who ate all the children in the country. Her sister Koromarange had a grand-daughter named ['Koa'kaŋgi] who, owing to the depredations of Prupe, was almost the last child left in the district. To prevent P. coming down to her camp, K. began suddenly to take her offerings of fish, food, herbs and grasses. P. became suspicious.

"Once upon a time I used to go down to K. That woman is very good to me. I will go down and see what she is doing. I feel she has a grand-daughter down there."

On one occasion she went across to ['Koro'maraŋ'gul], K. saw her and rushed out of the camp with a present of fish. As time went on Prupe lost her sight altogether. She wanted more than ever to catch the child.

By exchanging eyes with it she would be able to see once more. She came down again; K. was away, fishing with nets. The little girl cried out for water. P. gave her water, then seized her and escaped to her own camp at ['Prupa'ŋa-wand]. On her return K. missed the child, and tracked P. to her camp. She arrived just as her sister was about to operate on the eyes of the child. She pretended to be pleased that P. had found the infant and asked P. to fetch water for it, as she (K.) was tired from fishing. With a spear she poked a hole in a human skull water-dish and handed it to her sister. The dish leaked so badly that P. was a long time obtaining the water. Meanwhile K. prepared a snare and gave a deceiving cry, pleading for water. P. hastened into her camp with the water. She found K. had fled with the child and she had been tricked. She rushed out, was snared and, in her excitement kicked the fire; it blazed up, burnt her and the camp she was in. A great pit took the place of her camp. K. fled back to her camp and then away over the Coorong lagoon, by the shallow water-crossing to ['Juŋgu'ruŋ'bar], a high scrub-covered hill on [jurli], *i.e.*, on the ocean beach side. She looked back and saw the big fire blaze up as her evil sister perished.

SUMMARY

A legend of the Tanganekald, of the Coorong, South Australia, is transcribed and described, together with a sketch map illustrating some of the native place names recorded for the northern half of the Hundred of Glyde.

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LARVAL TREMATODES FROM AUSTRALIAN TERRESTRIAL AND FRESHWATER MOLLUSCS

BY T. HARVEY JOHNSTON AND E. R. CLELAND

Summary

Specimens of the terrestrial gastropod, *Succinea australis* (Ferussac), collected by Mr. F. Jaensch at Elwomple, near Tailem Bend, on June 24, 1937, were examined a month later, and in one a large pulsating sac which contracted rhythmically for some hours, was found alongside the liver. Upon dissection the main part of the sporocyst to which the sac was attached was uncovered. It consisted of a central portion from which arose about six juvenile pulsating structures and numerous knob-like, club-like and finger-like projections, many of the latter being of considerable length and ramifying for some distance through the tissues of the snail.

LARVAL TREMATODES FROM AUSTRALIAN TERRESTRIAL AND FRESHWATER MOLLUSCS

PART III. LEUCOCHLORIDIUM AUSTRALIENSE, N. Sp.

By T. Harvey Johnston, M.A., D.Sc., and E. R. Cleland, M.Sc.,
University of Adelaide

[Read 14 April 1938]

Leucochloridium australiense, n. sp.

Specimens of the terrestrial gastropod, *Succinea australis* (Ferussac), collected by Mr. F. Jaensch at Elwomple, near Tailem Bend, on June 24, 1937, were examined a month later, and in one a large pulsating sac which contracted rhythmically for some hours, was found alongside the liver. Upon dissection the main part of the sporocyst to which the sac was attached was uncovered. It consisted of a central portion from which arose about six juvenile pulsating structures and numerous knob-like, club-like and finger-like projections, many of the latter being of considerable length and ramifying for some distance through the tissues of the snail.

The main part of the sac (fig. 3) was white with distally-situated coloured bands, separated by slight constrictions. The most proximal of these bands was an incomplete brown ring, the second and third were complete brown bands, the fourth a pale shade of green, the fifth a complete brown ring, the sixth an incomplete brown band, and the tip of the sac was brown. Each of these rings was separated by a colourless band, in the centre of which (except between the fifth, sixth, and tip of the sac) was an opaque white line at the point of constriction.

The Cercariaeum

About twenty fully developed cercariaea were found in the large pulsating sac. Each was enclosed within a thick gelatinous sheath (fig. 2) interrupted at both the anterior and ventral suckers. In the outer part of the sheath faint concentric and radial lines were seen.

Each cercariaeum (figs. 1, 2, 4) was capable of much contraction and expansion, and a typical one was 616 μ long and 347 μ broad when contracted, and 308 μ broad when extended. The almost circular anterior sucker, which was surrounded by an elevated margin more pronounced dorsally, measured 193 μ across, and the mouth was subterminal on its ventral surface just below the tip. A powerful, almost circular, pharynx, 69 μ long, was present, and from its dorsal aspect arose a very short oesophagus. This divided almost immediately to form the two intestinal caeca which arched upwards and outwards, and then passed backwards on either side of the ventral sucker to the level of the genital pore.

The ventral sucker lying in the anterior part of the second half of the body was 154 μ in diameter. The anterior sucker, pharynx and ventral sucker (figs. 11, 12, 20) were formed of radiating muscle fibres associated with large vacuolate myoblasts with prominent nuclei. Circular sphincter-like and longitudinal to oblique muscle fibres were present just beneath the cuticle, while internally to the radial fibres they were most strongly developed. At the junction of the anterior sucker and pharynx the circular fibres were much more numerous, and at the rim of the two suckers were grouped to form sphincters.

The intestine was lined by cuticle and cuboidal cells, and beyond the latter a few circular muscle fibres.

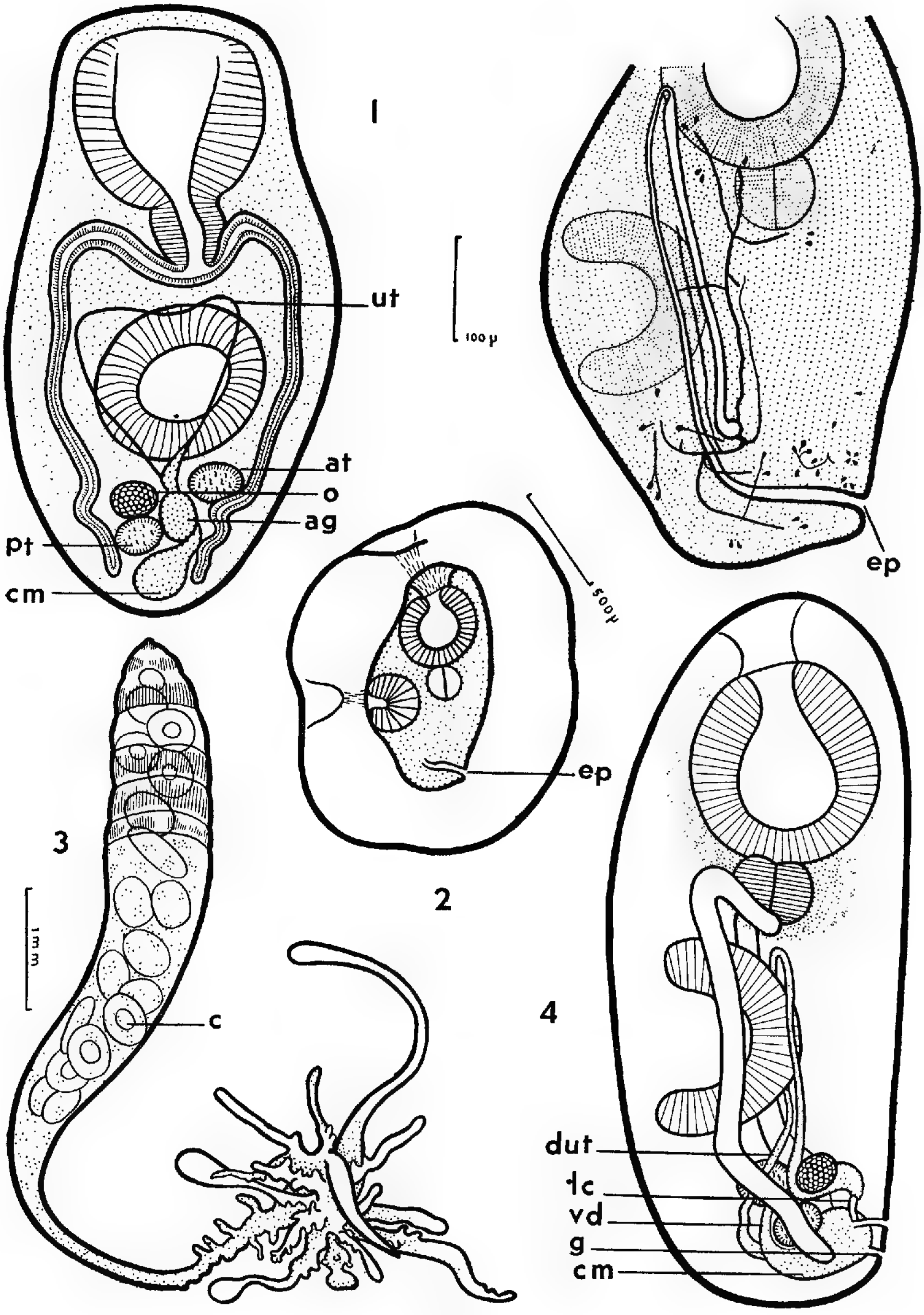
The general body surface was covered with a thick cuticle, but no trace of cilia was seen, though Magath (1920) and Zeller (1874) reported their presence in other species. Underlying the cuticle were circular, longitudinal and oblique muscle fibres supported by large connective-tissue cells (fig. 15). Scattered muscle fibres were seen throughout the body.

The nervous system (fig. 11) was typical and consisted of two lateral brain masses, one on either side of the anterior sucker and pharynx and connected dorsally by commissures. A large ventral nerve could be traced backwards on each side, and the root of each narrow dorsal nerve was seen. The anterior sucker was supplied by nerves from the brain.

Sense cells (figs. 13, 14, 20) were present on the surface of both suckers and an occasional minute one was seen in the cuticle of the body surface in the level of the pharynx. They were specially prevalent at the edge of the mouth and varied considerably in size, the largest being at the base of the anterior sucker immediately before its junction with the pharynx. They were either stalked or sessile, and consisted of a central clear parenchymatous part (fig. 14), in which was embedded the nerve fibrils, the whole surrounded by a substance having the consistency and colour of the cuticle. Dorsally and laterally from the pharynx a small number of cells similar to these in size and structure and staining properties were seen embedded in the parenchyma, but it is difficult to account for their function in such a situation.

Reproductive System

The two oval testes were diagonally placed, the anterior on the right-hand side (as viewed through a compound microscope) a little distance behind the ventral sucker; the posterior slightly dorsal to it but on the left-hand side. Above the posterior testis and slightly dorsal and median to it was the oval ovary, the three gonads thus forming a triangle (figs. 1, 4). In some specimens the ovary was found lying slightly in front of the anterior margin of the anterior testis. From the posterior testis the vas efferens (fig. 17) passed obliquely upwards ventral to the ovary and was joined by the shorter duct from the anterior testis. From this point the vas deferens (figs. 8, 16) travelled backwards, then turned sharply dorsally and passed through an undifferentiated cell mass to open at the



Figs. 1-5
Fig. 1, cercariaeum, dorsal view; 2, cercariaeum in sheath; 3, sporocyst and pulsating sac; 4, cercariaeum, lateral view; 5, excretory system.
Figs. 1 and 4 drawn to scale beside fig. 1; figs. 2 and 3 to scale indicated beside each.

gonopore on the dorsal side of the animal (figs. 6, 19, 20) a short distance from the posterior end. No seminal vesicle or true cirrus could be seen. The undifferentiated cell mass (figs. 1, 4, 6, 19, 20) near the gonopore was large and surrounded the end parts of the uterus and of the vas deferens, and thus could not be described at this stage as a cirrus sac. It gradually tapered ventrally and anteriorly away from the gonopore and then became separated into two parts, one of which surrounded the vas deferens and the other the uterus.

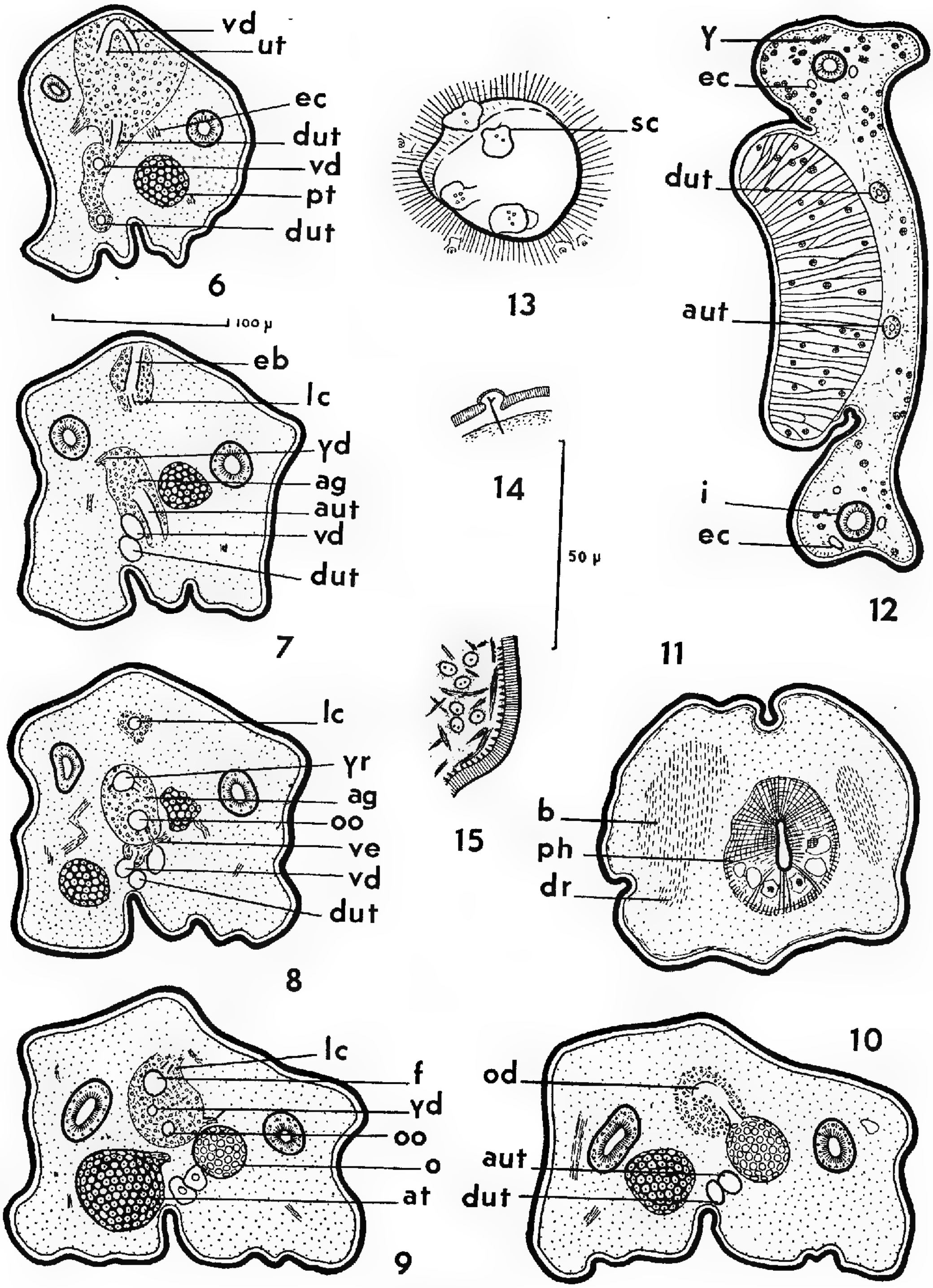
The short oviduct (fig. 10) travelled towards the mid-line, where it was joined by Laurer's canal (figs. 7, 8, 9, 19, 20), which passed posteriorly to enter the excretory canal just before the latter reached the excretory pore. Magath (1920, 109, 111) reported that a similar condition was present in *L. problematicum*, and was described by Looss (1899) for *L. insigne*. Near the junction of Laurer's canal with the oviduct was a slightly swollen part of the canal, probably the anlage of the fecundarium. The oviduct, after its junction with Laurer's canal, turned ventrally and was then joined by a very short vitelline duct (figs. 8, 9) which passed backwards to become widened into a small reservoir receiving the two yolk ducts. The latter ducts curved ventrally and anteriorly to the slightly developed yolk glands lying laterally from the intestinal caeca. Surrounding the oviduct, yolk reservoir and fecundarium was a large mass of undifferentiated tissue, the albumen gland (figs. 1, 4, 7-10).

After its junction with the yolk duct, the oviduct continued to the mid-ventral line, where it passed forwards into the ascending uterus (figs. 8, 9). This travelled upwards and outwards on the inner side of the anterior testis, formed a loop around the dorsal portion of the ventral sucker (figs. 1, 4) and descended on the other side, passing gradually towards the median line until, just behind the sucker, it lay alongside its ascending branch. It then proceeded posteriorly to the level of the gonopore, turned sharply dorsally, became associated with the tissue of the undifferentiated cell mass, and joined the vas deferens immediately before the latter opened at the gonopore.

Excretory System

The excretory pore (fig. 5) was on the dorsal surface immediately above the genital opening, and led into a small rounded excretory bladder (fig. 7). The latter received Laurer's canal dorsally (figs. 4, 7, 20), while laterally it gave rise to two main collecting tubes (fig. 6) which passed upwards, external to the intestinal caeca, to well beyond the base of the anterior sucker. Here these canals bent backwards until they reached the level of the posterior region of the sucker, where they became dilated just before giving rise each to an anterior and a posterior collecting tubule.

The anterior tubule passed forwards and, in the region of the ventral sucker, gave rise to a dorsal branch and a short ventral branch which appeared to join the main ascending tube; the main stem then continued to the level of the pharynx, where it divided into three branches; one of these passed dorsally



Figs. 6-15

Figs. 6-12, Tr. sections of cercariaeum; 7, 8, are consecutive sections; 13, sense cells at base of anterior sucker; 14, longitudinal section of sense cell; 15, longitudinal section of body wall.

Figs. 6-12 drawn to scale below fig. 6; figs. 13-15, to scale below fig. 14.

below the pharynx, while the second and third travelled forwards, one lateral and the other ventro-lateral to the pharynx.

The short posterior tubule almost immediately gave rise to several accessory branches. The first passed upwards alongside the anterior collecting tubule, the second between the ascending and descending main tubes; the third, fourth and fifth were terminal, the third proceeding anteriorly to end behind the ventral sucker, the median fourth lying between the other two and travelling backwardly towards but below the excretory bladder, and the fifth dorsally towards but above the bladder. The bladder and the proximal ends of the main excretory tubes were lined with cuticle.

The correct number and arrangement of the flame cells and excretory tubules could not be determined owing to the small number of cercariaea available for study, their thickness, and the small size of the flame cells. The figure and descriptions of this system, therefore, give only an approximation of their arrangement.

Relationships

The cercariaeum stage of *Leucochloridium australiense* differs from that of *L. macrostomum* (Rud.) and *L. problematicum* Magath in size, and also in the absence of cilia on the general body surface. It is slightly smaller than *L. macrostomum* which is 0·85 mm. long and 0·45 mm. broad, and much smaller than *L. problematicum* which is 2·2 mm. by 0·85 mm. The anterior sucker, pharynx and ventral sucker also differ considerably and in *L. australiense* are almost circular, measuring, respectively, 193 μ, 69 μ, and 154 μ in diameter. In *L. problematicum* they measure, respectively, 0·4 mm. long and 0·24 mm. wide; 0·17 mm. and 1·15 mm.; and the almost circular ventral sucker 0·34 mm.

Laurer's canal in the Australian species opens into the excretory bladder as in *L. problematicum,* and not on the dorsal surface as in *L. macrostomum;* while the intestine resembles that of the former species.

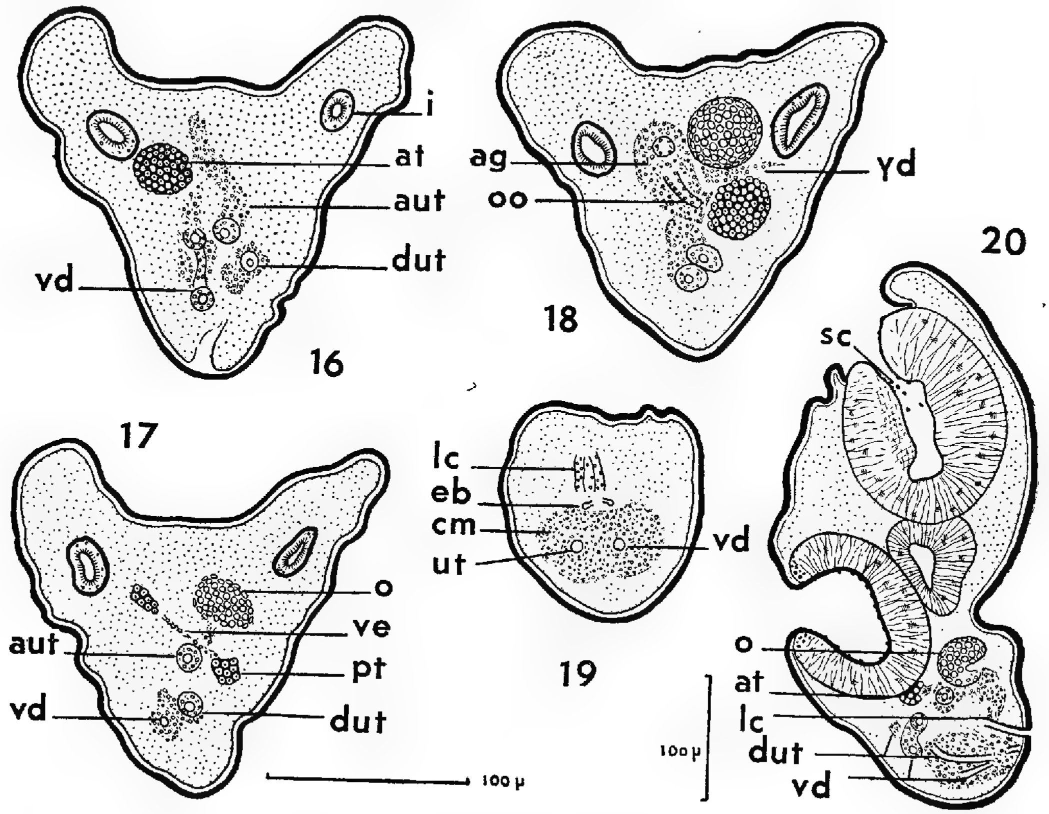
The reproductive system differs in the relationships of the ovary and the two testes from *L. assamense* Sewell (1922), and is similar to that of *L. macrostomum* and *L. problematicum,* except that in our specimens no true cirrus sac is present as the uterus and vas deferens pass together through an undifferentiated cell mass prior to opening at the gonopore. This condition may perhaps become altered in later larval development.

Our species appears to come nearest to *L. problematicum* and *L. insigne.* In the study of species of *Leucochloridium* more attention has been paid to the natural history of the mother sporocysts than to the cercariaeum, with the result that few of the latter have been adequately described. The first of these, *L. macrostomum* (Rud.), was described by Heckert in 1888 under the name of *L. paradoxum,* and an account of its histology, morphology and life history was given.

In 1920 Magath described a new species, *L. problematicum,* from North America, which greatly resembled the marita of *L. insigne* described by Looss in

1899 from European birds. Magath suggested that *L. problematicum* was the parthenita stage of *L. insigne,* although the host of the latter, *Fulica atra,* was stated not to occur in the region from which his material was derived. In view of later data on the host specificity of species of *Leucochloridium,* Magath's suggestion is probably incorrect.

Sewell, in 1922, described the third cercariaeum as *L. assamense,* which does not seem to us to be a typical member of the genus.



Figs. 16-20.
Figs. 16-19, longitudinal horizontal sections of cercariaeum; 20, longitudinal vertical section of cercariaeum. All drawn to same scale.

Sinitsin (1931, 796) gave a brief summary of investigation on the family Harmostomidae, and included a revised classification of the Harmostominae (thus excluding the Leucochloridiinae) and descriptions of various species. He pointed out that the parthenita stage of the latter is specific and the marita stage indiscriminate in regard to host relationship. But such a statement does not apply to the Leucochloridiinae.

McIntosh (1933) described six new species of *Leucochloridium* (marita stage) and included a key for the differentiation of all known species. This was largely based upon the distribution of the vitellaria, size of fecundarium, etc.;

characters which could not be determined satisfactorily in the larva, and were, therefore, not of much assistance to us in placing our new form. An important deduction from this paper, mentioned by Woodhead (1935), is that species of this genus are specific in their bird hosts.

Wesenberg-Lund (1931) gave a full account of the biology of *L. paradoxum (i.e., macrostomum)* and discussed the papers of Heckert, Magath and Mönnig. He believed that Magath had erected his new species *L. problematicum* on insufficient data, and suggested that the brown sacs described by that investigator in America belonged to the same species as those found by Heckert and Mönnig in Europe. But it seems to us possible that sporocysts, apparently similar, may give rise to different cercariaea. In one of his figures, Wesenberg-Lund (1931, 95, fig. 3) shows a cercariaeum from a brown sac and one from a green sac, and mentioned a slight difference in regard to the sizes of the suckers. His figure indicates the ratio of the anterior to the ventral sucker as 5:4 in the case of the cercariaeum from brown sac, and 1:1 from that from a green sporocyst. In his later figures (Wesenberg-Lund, 1934, pl. xxxii, figs. 7, 8) a slight difference is to be observed in the sucker ratio of the two cercariaea assigned to *L. paradoxum*. This ratio is 4:3 in the cercariaeum in fig. 8, and 10:9 in the cercariaeum in fig. 7, but Wesenberg-Lund does not state from what kind of sac they were obtained.

Lühe (1909, 209, fig. 188) has drawn a lateral view of the cercariaeum of *L. macrostomum*. Woodhead (1935) gave a description of four new *Leucochloridium* sacs, one of which is very like, and may prove to be identical with, that already described by Magath. He remarked upon the specificity of *Leucochloridium* maritae as regards their hosts, implied in McIntosh's paper, but this theory, according to Wesenberg-Lund (1931, 133, 134), is not substantiated on account of the presence of the maritae of *L. macrostomum* and *L. insigne* in a number of different bird hosts. In 1936 he referred to an extraordinary case of multiple infection of *Succinea retusa* with the sporocysts of *Leucochloridium*.

Gower (1936) gave a description of a new sporocyst of *Leucochloridium* from Louisiana and included a camera-lucida drawing of the cercariaeum. This, he stated, differed from *L. problematicum* in the sucker ratio, which was approximately 2:1 in his specimen, but he gave no account of the anatomy.

Yamaguti (1935, 173) described a new marita, *L. sime*, which resembled most closely *L. variae* McIntosh (1932).

Addendum

Since this paper was accepted for publication, Mönnig's (1922) important paper on *Leucochloridium macrostomum* has become available. His account of the female ducts does not agree with their disposition in our material, and we would suggest that he has probably confused the ascending and descending limbs of the uterus in the vicinity of the albumen gland. We were unable to find any connection between the albumen gland and the enlarged part of the descending uterus such as he indicates in his fig. 21.

The sense cells referred to in our paper as occurring in the vicinity of the mouth and pharynx may perhaps be similar to structures indicated in his pl. v, fig. 27, and which he has called "epithelial cells" and "pharyngeal pocket epithelium" respectively. The distribution of colouration of the pulsating sacs differs considerably for the Australian and European forms as figured by him.

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EXPLANATION OF LETTERING

All drawings were made with the aid of the camera-lucida, except fig. 5.

ag, albumen gland; at, anterior testis; aut, ascending limb of uterus; b, brain; c, cercariaeum; cm, undifferentiated cell mass; dr, dorsal root; dut, descending limb of uterus; eb, excretory bladder; ec, excretory canal; ep, excretory pore; f, fecundarium; g, gonopore; i, intestine; lc, Laurer's canal; o, ovary; oo, ootype; ph, pharynx; pt, posterior testis; sc, sense cells; ut, uterus; vd, vas deferens; ve, vas efferens; y, yolk glands; yr, yolk reservoir; yd, yolk duct.

SCOLYTIDAE AND PLATYPODIDAE CONTRIBUTION 49
NEW SPECIES FROM AUSTRLIA AND THE FIJI ISLAND WITH SOME REVISIONAL NOTES

BY KARL E. SCHEDL

Summary

In my first paper on the Australian Fauna[1] I neglected most of the Cryphalinae and merely recorded others. Since then the South Australian Museum has kindly placed more types at my disposition, which now affords me the opportunity to publish more on some of these very difficult species.

SCOLYTIDAE AND PLATYPODIDAE

CONTRIBUTION 49

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By KARL E. SCHEDL

[Read 14 April 1938]

In my first paper on the Australian Fauna [1] I neglected most of the Cryphalinae and merely recorded others. Since then the South Australian Museum has kindly placed more types at my disposition, which now affords me the opportunity to publish more on some of these very difficult species.

Other material I have received from the Imperial Institute of Entomology in London, the Dominion Museum at Wellington, New Zealand, and the Museum Royal d'Histoire Naturelle de Belgique at Bruxelles. Some of the original descriptions are so brief that determination necessitates a more detailed description, aside from some illustrations. Both shall be given below. From all the more difficult specimens balsam mounts of the antennae have been prepared.

HYLESINUS CORDIPENNIS Lea

Aside from the type, I have not seen any specimens. *Cordipennis* is a true *Hylesinus*, 3·3 mm. long, 1·7 times as long as wide, widest at the middle, oval in outline, the apical margin of the pronotum and the elytra broadly and similarly rounded. Elytral interstices with inconspicuous short and dark scales.

Leperisinus tricolor, n. sp.

A bright coloured species, 3·1 mm. long, 2·1 times as long as wide. Easily separated from the other Australian species, *L. bimaculatus* m., by its size and vestiture.

Front opaque, convex, densely granulate punctate, with short, rather dense and yellow pubescence, a shallow transverse impression just above the epistomal margin.

Pronotum wider than long (40:32), base bisinuate, postero-lateral angles rectangular, strongly rounded, sides feebly arcuate, subparallel on the basal half, strongly constricted in front, anterior margin moderately broadly rounded, disc with a strongly developed transverse impression along the anterior constriction, otherwise feebly convex, densely covered with short, small and dark reddish-brown scales, intermixed with scattered larger and pale yellowish ones, these more numerous along the median line behind and on the postero-lateral corners on each side of the median line with a dark semi-circular marking.

[1] Thirty-fifth Contribution, Records of the South Australian Museum, **5**, (4), 1936, 513-535

Elytra wider (49:40) and 2·1 times as long as the pronotum, each elytron broadly arcuate at the base, sides parallel up to the middle, then gradually narrowed, apex rather narrowly rounded, declivity commencing at the middle, gradually and somewhat obliquely declivous; striate punctate, striae very narrow, punctures indistinct, interstices feebly convex, densely covered with scales of different colour, each interstice also with a somewhat irregular double row of larger erect scales, ground colour a deep dark reddish-brown, with three wavy transverse and brighter coloured bands, the first near the base indistinct, produced by pale yellowish top scales only, the second more distinct, top and ground scales of the same colour, the third broad, on the declivital convexity and laterad abruptly ceasing, of a reddish-brown colour, another patch of similar colouration along the suture and on the sides behind.

Type in the author's collection.

Locality—Australia.

Hyleops, new genus

True *Hylesinidae* of the general shape as in some species of *Leperisinus* Reitter, with 7-segmented antennal funicle (fig. 1), large elongate 3-segmented

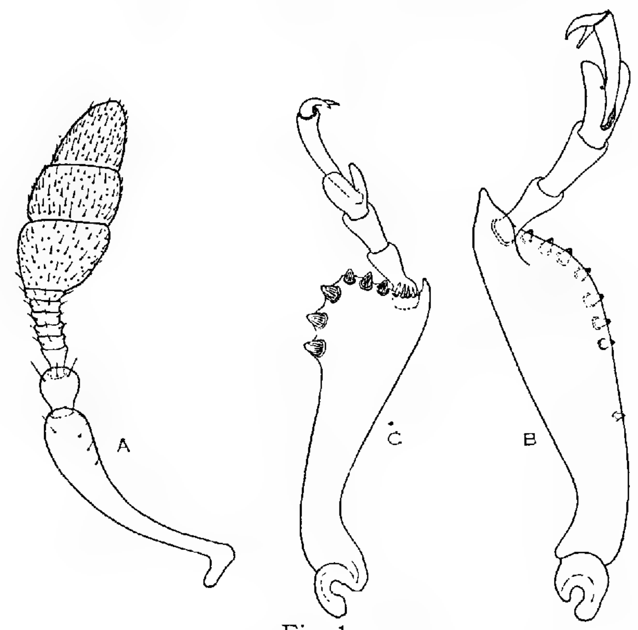

Fig. 1.
A: **Hyleops glabratus,** n. sp., antenna
C: Anterior tibia, **Leperisinus tricolor,** n. sp.
B: Ditto, **Hyleops glabratus,** n. sp.

antennal club, long oval eyes, finely and uniformly sculptured pronotum, striate-punctate elytra and ascending abdominal sternites. Characters which do not permit including it in any of the known genera are: the absence of scale-like vestiture on the pronotum and elytra, and especially the development of the front tibiae. The latter is widened distally, strongly compressed, with a series of small equal-sized serrations on the outer margin. All allied genera show at least on the front tibiae several large teeth on the apical edge. The groove for the reception of the tarsus is short and subtransverse, the front coxae are moderately remote.

Hyleops glabratus, n. sp.

Female—Dark reddish-brown, 3·4 mm. long, 2·2 times as long as wide.

Front convex, subshining below, opaque above, with a very shallow semicircular impression in the lower half, very densely and very finely punctured, with fine and inconspicuous pubescence.

Pronotum wider than long (15 : 10), widest in the basal third, base as in the allied genera strongly bisinuate, postero-lateral angles rectangular, feebly rounded, sides parallel on the basal third, obliquely narrowed in front, the anterior constriction hardly noticeable, apical margin moderately broadly rounded, disc feebly convex, without distinct impressions, very densely and very finely punctured, pubescence inconspicuous, pale yellowish and hair-like, median line hardly noticeable.

Elytra feebly wider and more than twice as long as the pronotum, sides parallel on more than the basal half, broadly rounded behind, declivity commencing at the middle, very gradually and somewhat obliquely declivous; disc shallowly striate punctate, the punctures rather small, shallow and indistinct on the sides, the first row moderately the other feebly impressed, interspaces subconvex, shining, irregularly and rather densely punctured, between the punctures finely wrinkled, the general appearance rather rough; declivity with the second interspace impressed, suture and third interstice elevated, each with a row of four to five tubercles, those of the third interspace larger; pubescence of the elytra dark and short, underside of the beetle covered with pale short and stout scales.

Male—Somewhat larger, the front broadly and shallowly concave, below the centre of the concavity and along the epistomal margin minutely reticulate, densely finely punctured above; pronotum with the anterior constriction more distinct, the elytra stouter, the declivity more oblique, the second interstice deeper and impunctate, the tubercle on the suture and third interstice decidedly larger, the entire declivity brightly shining, on the interspaces without puncturation.

Types in the Imperial Institute of Entomology and in the author's collection.

Locality—Nanango, Queensland, 14 September 1936, bred from Hoop Pine, A. R. Brimblecombe.

Phloesinus australis, n. sp.

Reddish-brown, 2·2 mm. long, 2·0 times as long as wide. The third species from the Australian Region. Easily recognised by its sculpture.

Front convex, transversely depressed below, finely granulate-punctate, less dense along the median line above epistomal margin; antennae as shown in fig 2.

Pronotum wider than long (33:26), widest at the base, the latter strongly bisinuate, postero-lateral angles rectangular, not rounded, sides broadly arcuate and feebly narrowed on the basal two-thirds, very strongly constricted in front, anterior margin narrowly rounded, disc moderately convex, surface shining, rather coarsely and densely punctured, median line impunctate on its greatest part. Scutellum small, hardly noticeable.

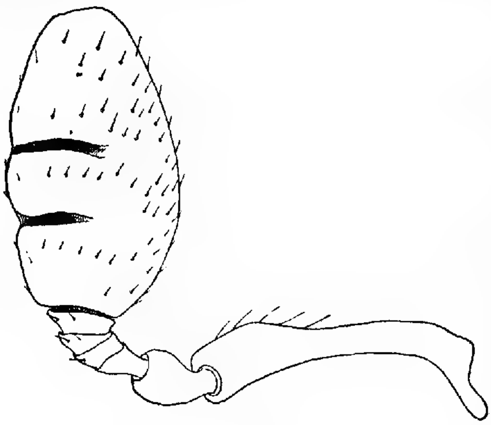

Fig. 2
Phloesinus australis, n. sp., antenna.

Elytra wider (36:33) and 1·8 times as long as the pronotum, sides parallel, broadly rounded behind, declivity commencing at the middle, evenly convex; disc striate-punctate, striae narrow, strial punctures not well defined, confluent in part, interstices shining, feebly convex, each with a row of large somewhat irregularly placed punctures; declivity with the striae more strongly impressed, the punctures more distinct, interspaces higher, the punctures replaced by good-sized tubercles, the second interstice without such and feebly impressed, pubescence short and yellowish.

Type in the author's collection.

Locality—Australia.

Pachycotes Sharp.

(Ent. Month. Mag., **14**, 1877, 10)

Redescription of the Genus

General shape long cylindrical, very similar to that in the genera *Dendroctonus* Er., *Hylurgus* Latr. and *Blastophagus* Eichh.

Front convex, more or less transversely impressed, the rostrum short and stout, antennal funicle 7-segmented, club pear-shaped, not at all compressed, 4-segmented.

Pronotum rather feebly convex, anteriorly with a well-developed constriction, usually with a well-defined impunctate smooth median line, sculpture uniform all over, punctate.

Elytra cylindrical, declivity convex, rather coarsely sculptured, ninth interspace carinate and serrate in the posterior half, projecting over the lateral margin, declivity usually with two types of vestiture, short, stout and densely placed scales and long stiff bristles. Tibiae triangularly widened distally, with apical teeth, abdominal sternites II-IV as long as V or II.

Pachycotes (Hylesinus) peregrinus Chap.

= *Pachycotes ventralis* Sharp

Chapuis' type is dark reddish-brown, 4·0 mm. long, 2·3 times as long as wide. Three specimens which I received from Dr. Clark, of the New Zealand State

Forest Service, and which apparently have been compared with Sharp's type, are somewhat larger, 4·8 mm. long, but otherwise agree in all respects with Chapuis' species.

Front convex, with a subcircular shallow impression between the eyes, the centre of it and the lower part of the median line polished and impunctate, remaining surface densely granulate-punctate. Epistomal process as in *Dendroctonus simplex* Lec.

Pronotum longer than wide (52:45), base strongly bisinuate, postero-lateral angles rectangular, feebly rounded, sides subparallel, then strongly narrowed, anterior constriction well developed, disc feebly convex, with a shallow transverse impression along the anterior constriction and a second one along the base, the latter more strongly developed on the sides; surface subshining, densely covered with large but shallow punctures, median line impunctate. Scutellum very small and shining.

Elytra hardly wider (58:52) and nearly twice as long as the pronotum, sides parallel, broadly rounded behind, declivity commencing behind the middle, evenly convex; disc deeply striate-punctate, strial punctures small and elongate, interspaces wide and convex, covered with densely placed transverse rugae; declivity with the strial punctures larger and more circular, the interspaces narrower, less convex, very finely and irregularly punctured and covered with very small scale-like hairs, each interstice also with a row of remotely placed small setose granules, the latter more strongly developed at the commencement of the declivital convexity.

The type is a male. The female has the front evenly convex, without the circular depression but with the median line finely carinate on the lower half.

Pachycotes australis, n. sp.

Male—Piceous, 3·7 mm. long, 2·2 times as long as wide. Of the same general shape as the genotype, but somewhat stouter and with different sculpture.

Front, convex above, flattened and feebly concave below, epistomal margin developed into an oblique transverse strip, the upper limit strongly elevated, especially in the middle, median line narrowly carinate on its lower third, entire surface subshining, sparingly and finely punctured, the centre of the impression impunctate.

Pronotum wider than long (50:38), general shape as in *P. peregrinus* Chap., the punctures larger, intermixed with some smaller ones, shallow and disclosing the bottom, near the apex and along the median line the punctures becoming smaller, more remotely placed and with the outer margins asperity-like elevated.

Elytra as wide (52:50) and twice as long as the pronotum, opaque, in outline and general shape as in *P. peregrinus* Chap., the declivity more strongly convex; the strial punctures shining and circular throughout, smaller on the declivity, interstices more coarsely and less densely wrinkled on the disc, between the rugae with minute irregularly placed punctures, declivity with the tubercles comparatively larger, the interspacial punctation very minute, the scales very densely placed.

The female is larger, 3·8 mm. long, somewhat more slender, the front dull, rather coarsely granulate-punctate, without median impression, but with an arcuate impressed line shortly above the similarly constructed epistomal margin; pronotum less strongly constricted in front, the sides more evenly rounded; the elytra with the rugae of the interspaces much coarser and comparatively fewer in number.

Types in the South Austrálian Museum, the Imperial Institute of Entomology and in the author's collection.

Locality—Dorrigo, New South Wales; Gallangowen, Queensland, ex Hoop Pine log, A. R. Brimblecombe, 18 January 1936.

Pachycotes clavatus, n. sp.

Male—Piceus, 3·6 mm. long, 2·2 times as long as wide. The peculiar frontal characters, the inseration of the antennal funicle and the sculpture separate this species easily from its allies.

Front deeply concave on the greatest part, concavity extending from eye to eye, epistomal margin beak-like as in the two foregoing species but more strongly developed, in the concavity with four high transverse carinae, vertex and genae finely remotely punctured. Antennal scape (fig. 3) club-shaped, funicle inserted before the apex antennal club furnished with long bristles.

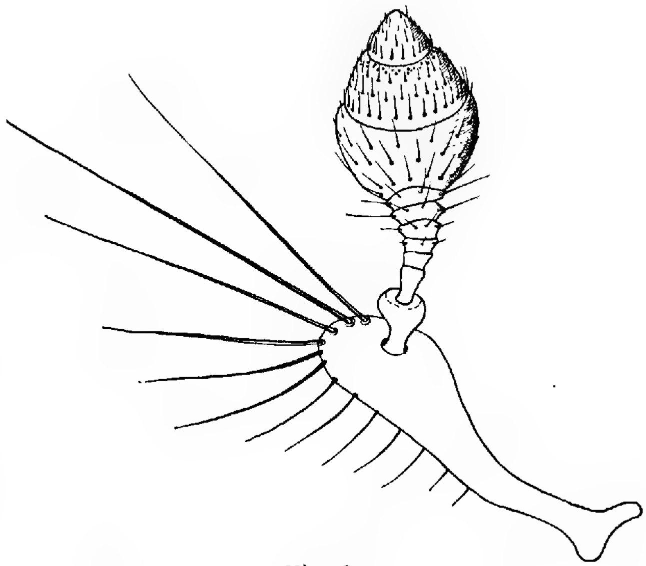

Fig. 3
Pachycotes clavatus, n. sp. antenna

Pronotum wider than long (50:36), base bisinuate, postero-lateral angles rectangular, feebly rounded, sides arcuate and narrowed towards the apex, anterior constriction strongly developed, disc feebly convex, anterior transverse depression well developed, surface subshining, punctures small, remotely placed, rather irregular in size. Front and pronotum with scattered reddish hairs. Scutellum hardly visible.

Elytra as wide (53:50) and twice as long as the pronotum, with a rather strongly convex declivity; disc with the striae hardly impressed, strial punctures extremely small, somewhat larger but hardly more distinct on the declivity, interspaces subshining, less convex than in the two preceding species, the uniseriate setose granules larger and on the first three interspaces extending over the apical two-thirds, on the basal third with rather fine and moderately closely placed transverse rugae, the irregularly placed small interspacial punctures numerous, the scales not as densely arranged as in *P. australis* (abraded ?), the declivital convexity slightly projecting over the apical margin.

Female with the front evenly convex, granulate-punctate, more strongly and densely so in the middle of the lower half, pronotum with the anterior constriction less distinct, elytra with the sculpture decidedly coarser.

Types in the Imperial Institute and in the author's collection.

Locality—Sydney (Imp. Inst.) and New South Wales.

Hylurdrectonus, n. g.

General shape and outline similar as in *Hylurgus* Latr. and *Dendroctonus* Er., but with different antennae and rather remarkable sexual characters. Pronotum feebly convex, not margined behind, abdomen cylindrical, elytral declivity convex, first visible sternite not much longer than III, IV or II.

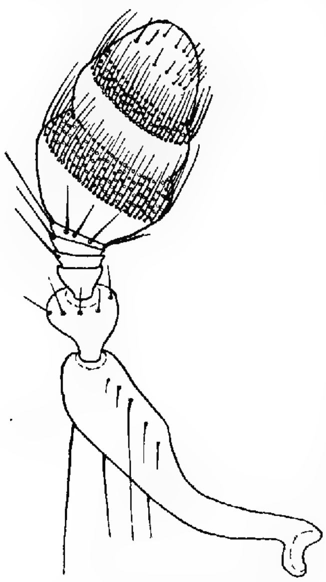

Fig. 4
Hylurdrectonus piniarius, n.sp.
antenna

Antennae with the funicle 5-segmented, the club but little compressed, with three distinct segments (fig. 4), fore coxae widely separated, anterior tibiae widened distally, with numerous teeth on the outer margin, metepisternum visible on its entire length.

Hylurdrectonus piniarius, n. sp.

Female—Piceus, 1·6 mm. long, 2·5 times as long as wide.

Front rather strongly convex, densely coarsely granulate-punctate, sparsely hairy. Eyes long oval, with a small emargination on both sides about in the middle.

Pronotum shining, as long as wide, base transverse, postero-lateral angles rectangular and feebly rounded, sides straight and feebly convergent on the basal two-thirds, with a distinct anterior constriction, broadly rounded in front; feebly convex, with a transverse depression short behind the anterior margin, moderately coarse and sparsely (especially along the median line) punctured on the disc, more densely so along the transverse depression, roughly granulate on the sides, pubescence very sparse; scutellum small, triangular.

Elytra wider (21 : 19) and 1·7 times as long as the pronotum, widest in the posterior half, sides subparallel, broadly rounded behind; declivity commencing behind the middle, evenly rounded; disc striate-punctate, the punctures coarse, closely placed and decreasing in size from the base to the declivity, interspaces shining, moderately wide, each with a row of smaller punctures, puncturation confused near the base, each interspacial puncture bearing a small erect reddish hair; declivity with the strial punctures obscure, first and second striae indicated by feebly impressed lines; second interstice feebly impressed, interstices one to three with a regular row of very fine granules, aside from these finely densely and irregularly punctured, the pubescence according to the puncturation very dense but much shorter than on the disc.

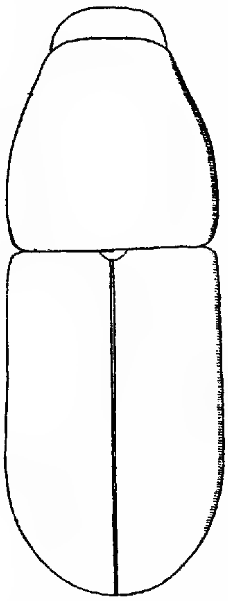

Fig. 5
Hylurdrectonus piniarius, n. sp. dorsal aspect ♀

Male—Somewhat stouter and more shining.

Front convex, with a triangular depression below, which is impunctate along the median line.

Pronotum as in the female.

Elytra with the first striae strongly impressed on the disc, punctures not visible, the other rows not impressed, the punctures small and remotely placed, interspaces wide, each with a few rather irregularly-placed punctures of varying size, these more regular in arrangement, larger and deeper on the sides (interspaces 5 to 9); declivity more oblique, commencing in the middle, suture and third interstice broadly elevated, each with a row of large but remotely placed granules, interspaces polished, each with very scattered and minute punctures, the second broadly impressed, strial punctures not recognisable, pubescence according to the puncturation of the interspaces extremely sparse and short.

Types in the Imperial Institute and in my collection.

Locality—Queensland, A. R. Brimblecombe, Yarraman, February, 1934, from axes of Hoop Pine cones.

Letznerella (Cryphalus) tricolor Lea

Redescription of Type—Reddish-brown, 1·4 mm. long, 2·3 times as long as wide. The antennae (fig. 6) and the sculpture of the elytra refers this species to the genus *Letznerella* Reitt. The genus *Ernoporides* Hopkins with *Cryphalus jalappae* Reitt. as genotype is synonymous with *Letznerella* Reitt. and has to be withdrawn.

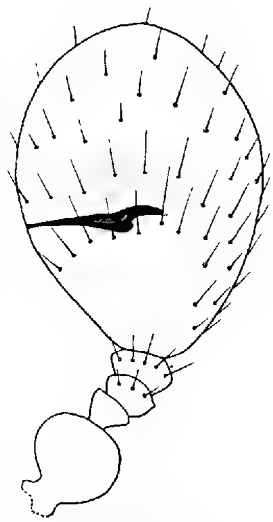

Fig. 6
Letznerella (Cryphalus) tricolor Lea, antenna

Front convex, densely granulate-punctate, subshining above, rather opaque and nearly black below.

Pronotum wider than long, base feebly bisinuate, postero-lateral angles rectangular and distinctly rounded, broadly arcuate in front, summit at the middle, anterior margin armed with numerous pointed and recurved asperities, anterior area asperate, the first asperities arranged in broken concentric ridges, more crowded and irregularly placed around the summit, posterior area densely punctured, from each puncture arising a short blunt yellowish scale.

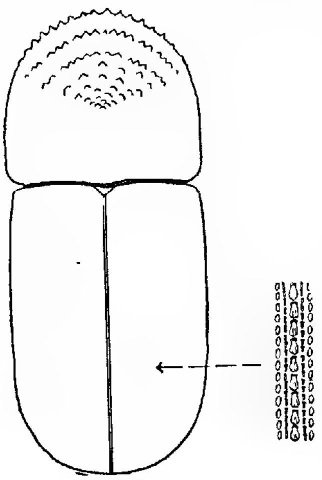

Fig. 7
Letzuerella (Cryphalus) tricolor Lea
dorsal aspect and elytral detail

Elytra but little wider and not quite twice as long as the pronotum, sides parallel on the basal half, broadly rounded behind, declivity commencing shortly behind the middle, evenly convex; striate-punctate, striae but feebly impressed, strial punctures moderate in size, interspaces flat, each with a row of large and blunt pale yellow scales, each such row of scales bordered on each side by a row of much smaller, more slender and more hair-like scales, the development of scale vestiture on the declivity more distinct than on the disc.

I have seen a good series of this species in the material of the Imperial Institute of Entomology, of which the labels say: Queensland, per R. Veitch, on *Melittia megasperma,* Imbil, on native Wistaria, R. Brimblecombe, 24 November 1936.

Erioschidias, n. g.

General shape as in most *Cryphalinae,* antennal funicle 3-segmented (fig. 8), club very large, with the sides evenly rounded, without sutures or septa on either side but with scattered pores and setae. Pronotum with the anterior margin armed by asperities. Anterior coxae touching, anterior tibiae with numerous teeth imbedded in well-developed sockets. Metepisternum largely covered by the elytra.

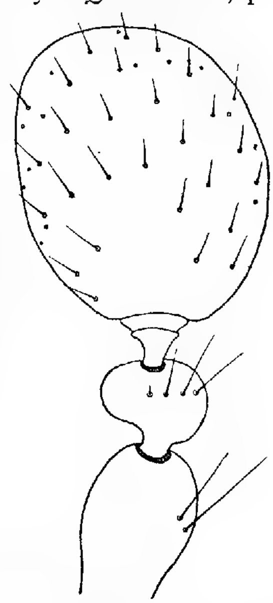

Fig. 8
Erioschidias (Cryphalus) setistriatus Lea, antenna

Erioschidias (Cryphalus) setistriatus Lea

Redescription of the Type—Piceus, 1·4 mm. long, 2·5 times as long as wide.

Front plano-convex, feebly transversely depressed below, with faint scratches radiating out from the middle of the epistomal margin, very finely punctulate. Eyes rather large, shortly oval, with a distinct emargination in front.

Pronotum as long as wide, widest in the basal third, base finely margined and feebly bisinuate, postero-lateral angles obtuse, not rounded when viewed from above, sides gradually rounded to the apex, anterior margin with two small asperities medially, summit in the middle, with a distinct transverse depression behind it, anterior area moderately steeply convex, densely covered with low more or less tubercle-like asperities, these assume the appearance of granules towards the posterior half of the pronotum, the entire surface giving the impression of being densely coarsely granulate, covered with small yellowish scales.

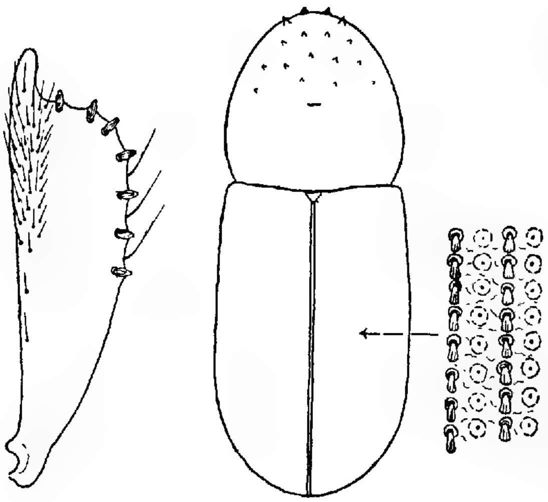

Fig. 9
Erioschidias (Cryphalus) setistriatus Lea, dorsal aspect of the adult beetle, detail of elytral sculpture and fore tibia

Elytra but little wider (47:43) and 1·6 times as long as the pronotum, widest in the middle, sides subparallel, moderately broadly rounded at the apex, declivity commencing behind the middle, gradually convex; disc shallowly striate-punctate, the punctures large, extremely shallow, disclosing the bottom, interspaces flat, about twice as wide as the diameter of the strial punctures, each interspace with a row of smaller more remotely placed punctures on a feebly raised line, each puncture with a short stout erect pale yellowish scale, remaining surface of the interspaces irregularly reticulate, thus producing a subshining rather rough appearance of the entire elytra; declivity with the scales somewhat larger, first and last visible sternite subequal in length, much longer than the third or fourth, the second but little longer than the first.

Apart from the types I have not seen any specimens.

Erioschidias queenslandi, n. sp.

Yellowish-brown, 1·7 mm. long, 2·4 times as long as wide. From *E. setistriatus* Lea easily separated by the size, sculpture and general shape.

Front opaque, plano-convex, densely minutely punctulate, flattened in the median half. Eyes short oval, emarginate in front. Antennae with the third segment extremely small, club circular in outline, pubescence rather dense, sensitive pores numerous.

Pronotum wider than long, base bisinuate, posterolateral angles rectangular, rounded when viewed from above,

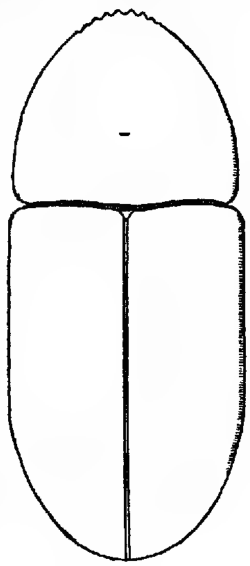

Fig. 10
Erischidias queenslandi, n. sp., dorsal aspect

sides arcuate and convergent on more than the basal half, anterior margin rather narrowly rounded, armed with numerous small asperities; summit behind the middle, anterior area obliquely convex, densely covered with small asperities which are not connected at their bases to form concentric ridges, posterior area densely roughly granulate punctate. Scutellum small.

Elytra shining, but little wider and 1·8 times as long as the pronotum, humeral angles feebly rounded, sides parallel on the basal half, apex narrowly rounded, declivity commencing at the middle, gradually declivous; disc with rows of hardly visible shallow punctures, interspaces flat, apparently uniseriately minutely punctate, on the declivity these punctures replaced by small very densely placed granules, from the interspacial punctures and granules respectively arise short erect yellowish hair-like bristles.

Types in the South Australian Museum and in the author's collection.

Locality—Cairns district, A. M. Lea.

Hypothenemus (Cryphalus) tantillus Lea

Redescription of the Type—Yellowish-brown, 1·0 mm. long, 2·4 times as long as wide. One of the smallest species of the genus.

Front convex, feebly transversely depressed below, densely rugose, sparsely hairy, with a faint median tubercle.

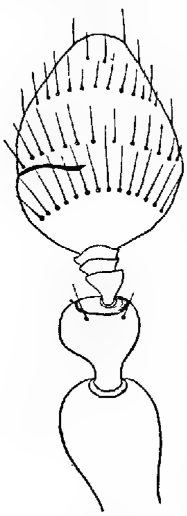

Fig. 11.
Hypothenemus (Cryphalus) tantillis Lea, antenna.

Pronotum wider than long (38:32), base feebly bisinuate, postero-lateral angles feebly rounded, sides and apex conjointly rounded, anterior margin armed with four recessed asperities; strongly globose, summit at the middle, followed by a distinct transverse depression, anterior area strongly convex, with numerous low asperities, posterior area very densely rugosely punctured, pubescence short but rather dense. Scutellum small, indistinct.

Elytra as wide and not quite twice as long as the pronotum, sides parallel, broadly rounded behind, declivity commencing behind the middle, evenly convex; disc lineate-punctate, the punctures shallow and moderately large, separated from each other by half of the diameter of one puncture, interspaces flat, finely punctulate, therefore subshining, not much wider than the rows of punctures, each puncture bears a small inclined yellowish hair, two rows of similar incon-

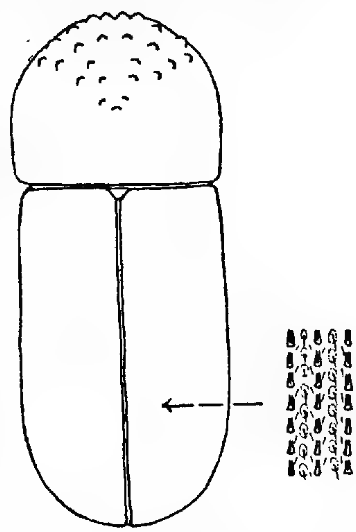

Fig. 12
Hypothenemus (Cryphalus) tantillus Lea,
dorsal aspect and detail of elytral sculpture

spicuous hairs on the interspaces close to the main striae, in the middle of each interspace with a row of pale yellow erect and rather broad scales, these scales are inconspicuous on the basal half and become more and more developed towards the declivity. Apart from the type I have not seen any specimens.

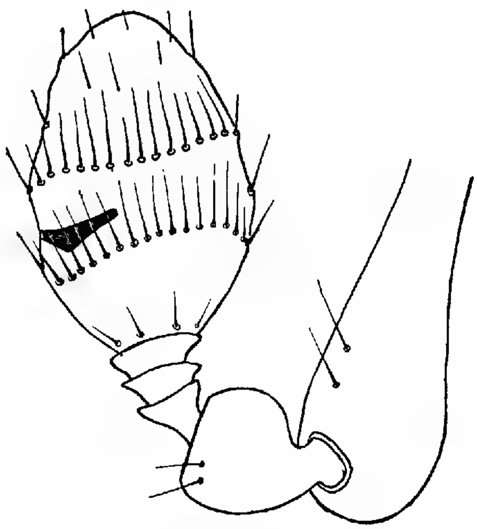

Fig. 13
Hypothenemus (Cryphalus) striatopunctatus Lea, antenna

HYPOTHENEMUS (CRYPHALUS) STRIATOPUNCTATUS Lea

Redescription of the Type—Yellowish, 1·3 mm. long, 2·4 times as long as wide.

Front evenly convex, densely granulate punctate.

Pronotum wider than long (18: 13), base bisinuate, postero-lateral angles rectangular, feebly rounded, sides and apex conjointly broadly arcuate, anterior margin feebly extended (not visible when viewed from above) and armed with two pointed recurved asperities medially; summit before the middle, anterior area very steep, perpendicular below, sparingly asperate on a comparatively small area, posteriorly the summit coarsely and very densely punctured. Scutellum distinct.

Elytra as wide and more than twice as long as the pronotum, humeral angles rounded, sides parallel on more than the basal half, rather narrowly rounded behind, declivity commencing behind the middle, gradually declivous; disc coarsely striate-punctate, the strial punctures subquadrate near the base, circular behind, interspaces narrow, convex and each with a row of scale-like hairs, these are more slender in the basal half of the elytra, broader and more like true scales behind.

The specimens recorded by the author in the Records of the South Australian Museum, **5**, 1936, 527, have been misidentified. After comparison with the type they must be referred to a new species.

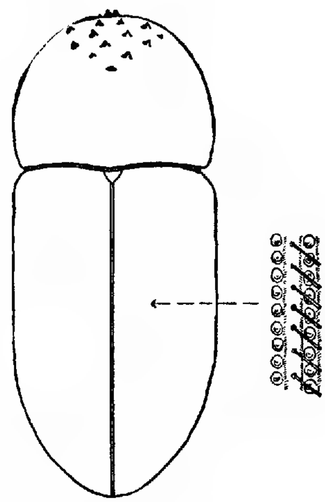

Fig. 14
Hypothenemus (Cryphalus) striatopunctatus Lea, dorsal aspect and elytral detail

Stephanoderes (Cryphalus) melasomus Lea

Redescription of the Type—Piceus, 2·1 mm. long, 2·4 times as long as wide. Front convex, feebly transversely depressed below, minutely longitudinally wrinkled, median line shining below, with a low convexity centrally, sparsely hairy.

Pronotum wider than long (41 : 33), base bisinuate, postero-lateral angles obtuse and rounded, sides uniformly and broadly arcuate to the apex, summit reddish-brown, shortly before the middle; strongly globose, anterior margin with two pointed asperities, anterior area with a few similar but blunter ones below, with some smaller ones which are partly connected at their base shortly before the summit, posterior area densely rugosely punctured; rather densely covered with hairs. Scutellum very inconspicous.

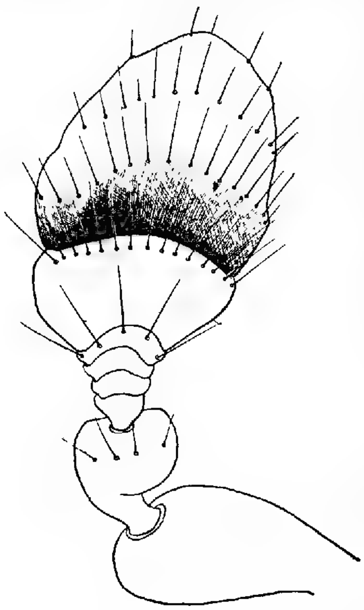

Fig. 15
Stephanoderes (Cryphalus) melasomus Lea, antenna

Elytra as wide and twice as long as the pronotum. sides parallel beyond the middle, obliquely narrowed behind, apex narrowly rounded, declivity commencing shortly behind the middle, obliquely convex; disc feebly striate-punctate, punctures moderate in size, as far apart as one diameter of a puncture, the striae feebly impressed, interspaces four times as wide as the striae, somewhat irregularly triseriately and finely punctured, the punctures of the median row bear small dirty yellowish erect scales, each puncture of the lateral rows a small short inclined concolorous hair; declivity with the striae strongly impressed, the interspaces strongly convex, the scales of the disc replaced by long erect dark brown and stout bristles, the hairs of the lateral rows by short brown inclined scales.

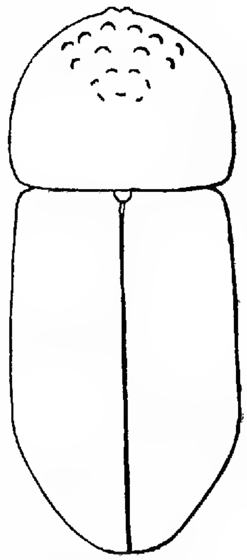

Fig. 16
Stephanoderes (Cryphalus) melasomus Lea, dorsal aspect

Cryphalus compactus Lea

Redescription of Type—Pale yellowish-brown, 1·8 mm. long, not quite twice as long as wide. The cotype Lea mentions from the Upper Ord river is not a variety but a good species.

Front convex, densely finely granulate punctate, with short yellow pubescence.

Pronotum wider than long (29 : 22), widest near the base, apex narrowly rounded, apical margin armed with several small and low asperities; summit behind the middle, anterior area steep, rather coarsely asperate, posterior area minutely punctulate.

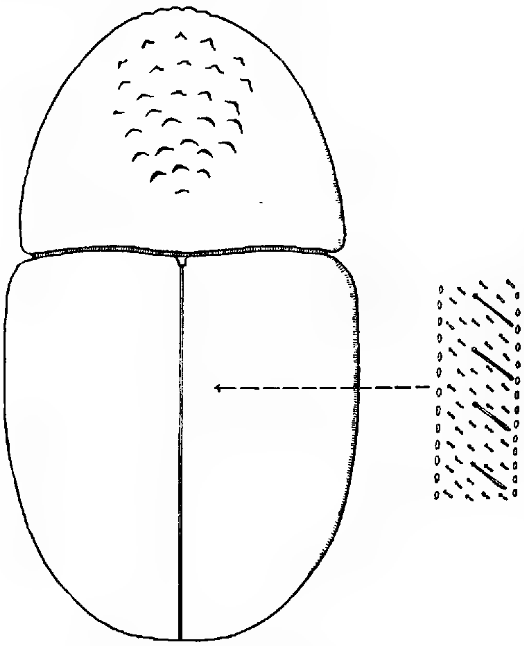

Fig. 17
Cryphalus compactus Lea
dorsal view of type and detail of vestiture

Elytra as wide (30: 29) and more than twice as long as the pronotum, widest at the base, broadly rounded behind, declivity uniformly convex, commencing at the middle, minutely and very densely punctured, the row hardly perceptible, vestiture double, ground scales very small and yellow, darker on the sides, uniseriate top-scales longer hair-like and somewhat darker.

Outside the type series the author has not seen any specimens.

Cryphalus subcompactus Lea

Redescription of Type — Piceus, 1·5 mm. long, 2·2 times as long as wide.

Front plano-convex, subopaque, very finely and densely punctured, with a narrow transverse carina separating vertex and frons.

Pronotum wider than long (23: 18), base feebly bisinuate, postero-lateral angles obtuse, hardly rounded, sides and apex conjointly broadly arcuate, apical margin armed with several low asperities, summit short behind the middle, rather strongly convex, anterior area densely asperate, posterior area densely punctulate.

Elytra about as wide and not quite twice as long as the pronotum, humeral angles rounded, sides parallel on the basal half, broadly and somewhat angulately rounded behind, declivity evenly convex and commencing at the middle; vestiture dark and of similar development as in *C. compactus* Lea; the striae feebly but distinctly impressed throughout.

The cotype which Lea mentions as being immature and slightly different is probably the other sex. It is somewhat more slender, the pronotum more narrowly and angulately rounded in front and the elytral scales more distinct.

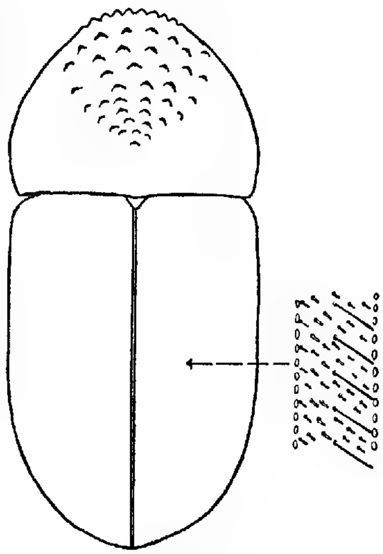

Fig. 18
Cryphalus subcompactus, Lea
dorsal aspect and elytral detail

HYPOCRYPHALUS Hopk. and DACRYPHALUS Hopk.

The generic differences between *Hypocryphalus* and *Dacryphalus* seem to me not very convincing, especially because Hopkins did not say much about the retuse elytral declivity in the description of the species. To use the number of sutures, more correctly the rows of bristles, indicating the number of sutures for separating the genera, even in a group where antennal characters are of greatest importance, will hardly prove of value. Therefore, the question still has to be settled whether both genera stand or one of them has to be withdrawn. For the present I unite the species having a 5-segmented antennal funicle, the club more or less evenly rounded in outline, and with the sutures indicated by rows of bristles on both sides of the latter under the name of *Hypocryphalus* Hopk. When more is known about the variation of the elytral sculpture, etc., and characters have been found to justify the separation in the sense of Hopkins, it will be easy to refer corresponding species to the genus *Dacryphalus* Hopk. again.

HYPOCRYPHALUS (CRYPHALUS) ASPER Broun

The Dominion Museum at Wellington and Dr. Clark of the New Zealand Forest Service have sent types and metatypes of *Cryphalus* [*Tomicus*] *asper* Broun to the author. A close examination reveals the fact that this species belongs not to the genus *Cryphalus* but to the more recently described genus *Hypocryphalus* Hopkins.

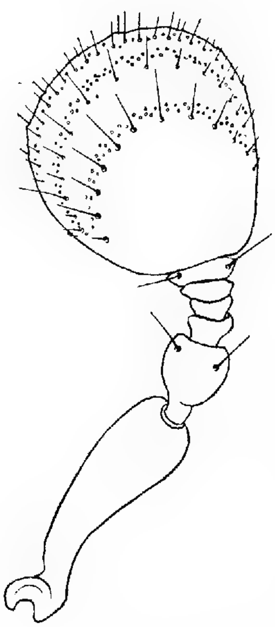

Fig. 19
Dacryphalus asper Broun
antenna

Redescription of the Species

Female—Brown, 2·3 mm. long, 2·3 times as long as wide.

Front subopaque, convex, densely granulate-punctate, eyes short oval, narrowly and shallowly emarginate in front.

Pronotum wider than long (33:25), widest at the base, the latter bisinuate, sides obliquely narrowed from the base to the apex, moderately broadly rounded in front, summit far behind the middle, anterior margin with a row of small inconspicuous asperities, anterior area obliquely ascending, with numerous low asperities, these more numerous around the summit, extending to the base at the middle, partly connected at their base thus forming broken ridges, densely punctulate on the sides behind, pubescence sparse and erect. The asperate portion laterally ceasing on nearly straight lines, which enclose an angle of about 60 degrees.

Elytra wider (35:33) and twice as long as the pronotum, humeral angles broadly rounded, sides parallel on the second and third fifth of the total length, broadly rounded behind, cylindrical, declivity commencing in the apical third, steeply obliquely convex; disc shallowly striate punctate, strial punctures rather small and indistinct, striae but feebly impressed, interstices wide and shining, very densely and finely punctured; the declivity feebly impressed along the suture, lateral convexities distinct, first and second striae impressed and the punctures indistinct, the suture feebly elevated, all interstices densely covered with minute, dark and erect scale-like hairs, additional to the sparingly placed long hairs.

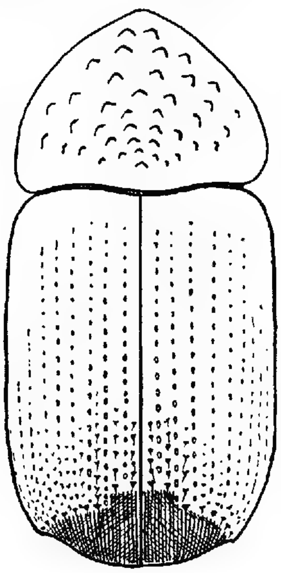

Fig. 20
Dacryphalus asper Broun, male, dorsal aspect

Male—Of similar size and proportions, the pronotum more narrowly rounded in front, the summit higher, the asperities not so frequently connected at their bases; elytral disc with the striae more distinct, the declivity with the lateral convexities higher, gradually declivous on the first two interstices, the third abruptly ceasing and more strongly tuberculate, the others similar but lower towards the sides.

Hypocryphalus spathulatus n. sp.

Reddish-brown, anterior area of the pronotum dark brown, 2·1 mm. long, 2·0 times as long as wide.

Front subopaque, feebly convex, moderately finely regularly and closely punctured, interspaces minutely punctulate.

Pronotum much wider than long, base bisinuate, postero-lateral angles hardly rounded when viewed from above, sides conjointly rounded from the base to the apex, the latter feebly extended, anterior margin with six well-developed asperities, summit in the posterior third, anterior area obliquely convex, with coarse asperities which extend not quite to the base, postero-lateral areas strongly densely punctured, pubescence sparse, short and inconspicuous. Base distinctly margined. Scutellum reduced to a hardly noticeable puncture.

Elytra as wide and 1·5 times as long as the pronotum, sides parallel to the middle, broadly rounded behind, declivity commencing at the middle, gradually convex; disc striate-punctate, punctures closely placed, striae feebly impressed, interspaces twice as wide as the striae, very densely and finely but deeply punctured, in the middle of each interspace with a more regular row of punctures which bear short erect hairs, from the other interspacial

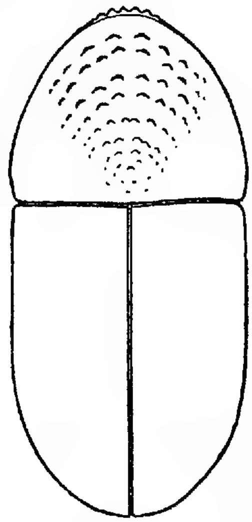

Fig. 21
Hypocryphalus spathulatus, n. sp., dorsal aspect

punctures arise short fine and more inclined hair-like scales, the double pubescence more distinct on the declivity.

Types in the South Australian Museum and in the author's collection.

Locality—Cairns district, A. M. Lea.

Xyleborus (Tomicus) acanthurus Lea

Tomicus acanthurus Lea has to be transferred to the genus *Xyleborus*. The redescription will facilitate the determination.

Female—Pale reddish-brown, 7·2 mm. long, not quite twice as long as wide.

Front convex, densely roughly punctured, eyes large and emarginate in front.

Pronotum wider than long (37:25), globose, base transverse, postero-lateral angles rectangular but not rounded, sides and apex conjointly rounded, median portion of apex feebly extended and armed with several low and blunt serrations, summit behind the middle, anterior area steep, asperate all over, the asperites larger and more remotely placed in front, small and crowded on the summit behind. Scutellum large, triangular and polished.

Elytra feebly wider (39:37) and twice as long as the pronotum, widest in the median third, broadly rounded behind, declivity commencing before the middle, broadly sulcate-depressed, the lateral margins moderately elevated, and armed with numerous teeth, the fundus deeply striate-punctate, strial punctures moderate in size, disc-like, interspaces convex, with numerous minute setose granules; elytral disc lineate-punctate, interspaces flat, rather densely irregularly punctured, punctures of equal size to those of the striae, therefore the rows hardly perceptible. Metepisternum narrow, densely punctured, the fore coxae touching, abdominal sternites I and II equal in length, each as long as sternite III and IV together. Apart from the type, no other specimen seems to exist.

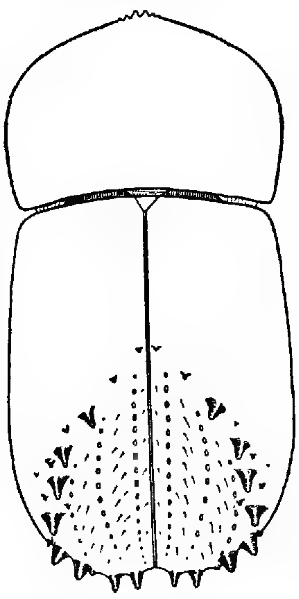

Fig. 22
Xyleborus acanthurus Lea, female, dorsal view

Xyleborus fijianus n. sp.

Female—Dark reddish-brown, 3·8 mm. long, twice as long as wide. A very distinct species within the *retusus-gravidus* group.

Front feebly convex, dull, rather finely punctured, interspaces minutely punctulate, impunctate along the median line, sparsely hairy except for a fringe of densely placed downwards-directed reddish hairs along the epistomal margin.

Pronotum wider than long (54:48), base distinctly bisinuate, postero-lateral angles obtuse and hardly rounded when viewed from above, sides and apex conjointly broadly arcuate, side margins acute in the posterior half, apical margin produced downwards and armed with two pointed asperities; very strongly globose, summit in the middle, anterior area very steep, covered with numerous low and small asperities, summit transverse, posterior area very finely and densely punctured, the interspaces reticulate. Pronotum and elytra densely covered by reddish inclined hairs. Scutellum small.

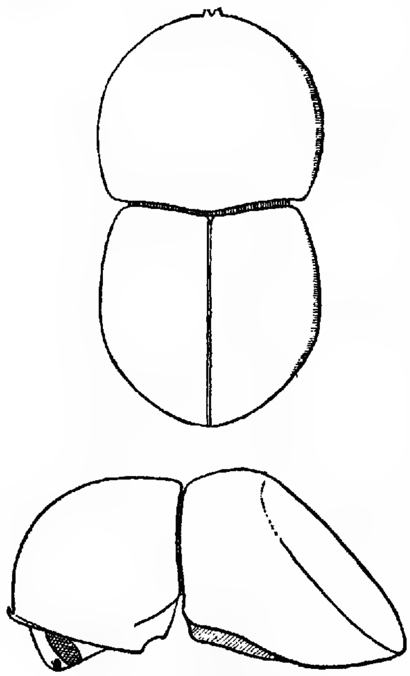

Fig. 23
Xyleborus fijianus, n. sp., dorsal and lateral aspect

Elytra as wide and but little longer (51 : 48) than the pronotum, humeral angles strongly rounded, sides subparallel on the basal half, broadly rounded behind, declivity commencing before the middle, obliquely truncate, apical margin acute up to the seventh interspace; disc very densely, finely and irregularly punctured, without indications of rows; declivital face with the first striae impressed, but without recognisable punctures, those striae corresponding to the second and third row similarly impressed in the posterior half, the entire declivital face flattened on its greater part, feebly convex on the sides. Anterior tibiae widened distally and with numerous small serrations on the outer margin. The femur and tarsi yellow, the tibiae dark reddish-brown.

Types in the collection of the Imperial Institute of Entomology, and in my own.

Locality—Fiji Islands, Taverne Quilai, 800 feet, October 18, 1924, Dr. H. S. Evans.

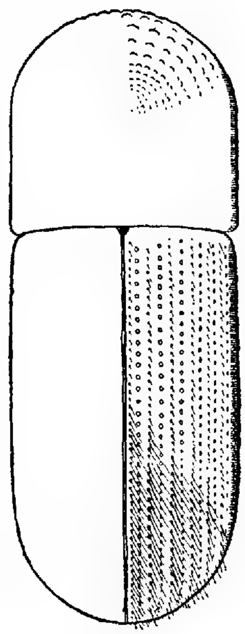

Fig. 24
Xyleborus eucalypticus, n. sp., dorsal aspect

Xyleborus eucalyticus n. sp.

Female—Piceus, anterior half of the elytra and legs flavescens, 1·8 mm. long, 2·7 times as long as wide. This species has to be placed near *X. laevies* Egg.

Front plano convex, minutely punctulate, subshining, with a few shallow punctures and with sparse pubescence along the epistomal margin.

Pronotum as long as wide, base feebly arcuate, postero-lateral angles rectangular and feebly rounded, sides parallel on the posterior half, broadly rounded in front, summit in the middle, anterior area feebly convex, rather densely covered by small low asperities, posterior area subshining, minutely punctulate and finely punctured, pubescence very sparse. Scutellum small, triangular.

Elytra as wide and 1·8 times as long as the pronotum, humeral angles feebly rounded, sides subparallel on more than the basal half, broadly rounded behind, declivity commencing behind the middle, uniformly convex; disc lineate-punctate, punctures very small, one from the other as far apart as the double diameter of one puncture, interspaces flat, four times as wide as the punctures of the rows, somewhat reticulate, each interspace with a row of very fine punctures which are somewhat closer placed than those of the main rows; behind the middle and on the declivity the interspacial punctures replaced by minute setose granules, the apical margin acute up to the seventh interspace.

Types in the collection of the Imperial Institute, and my own.

Locality—North Queensland, Geagana, June 15, 1934, ex *E. palmerstoni*, T. H. Smith, per R. Veitch.

NOTES AND EXHIBITS

Rediscovery of the Bivalve *Psammobia kenyoniana* Prit. & Gat., 1904, in South Australia. This rare shell is known only from odd valves from Airey's Inlet, Victoria, a solitary valve from Tasmania and a single right valve dredged from 22 fathoms in Investigator Strait, South Australia, by Sir Joseph Verco about 40 years ago, but not identified until 1934. It is interesting to record and exhibit a second valve (left) recently dredged, 1938, by the Fisheries boat in the same locality as Verco's specimen.

B. C. Cotton

15 April 1938

THE RED-BROWN EARTHS OF SOUTH AUSTRALIA

BY C. S. PIPER

Summary

From an economic standpoint the red-brown earths constitute one of the most important soil groups in South Australia, the most productive wheat-growing areas being on soils of this type. These soils assumed considerable importance at an early period in the settlement of the State, both on account of their geographical situation and the readiness with which they could be brought into pastoral or agricultural production. However, following the initial period of development, there was a general decrease in their fertility, and it was not until after the introduction of superphosphate towards the close of last century, and the adoption of better farming methods, that increased yields were obtained.

THE RED-BROWN EARTHS OF SOUTH AUSTRALIA

By C. S. Piper
(Waite Agricultural Research Institute, University of Adelaide)

[Read 14 April 1938]

I INTRODUCTION

From an economic standpoint the red-brown earths constitute one of the most important soil groups in South Australia, the most productive wheat-growing areas being on soils of this type. These soils assumed considerable importance at an early period in the settlement of the State, both on account of their geographical situation and the readiness with which they could be brought into pastoral or agricultural production. However, following the initial period of development, there was a general decrease in their fertility, and it was not until after the introduction of superphosphate towards the close of last century, and the adoption of better farming methods, that increased yields were obtained.

The principal occurrence of these soils is along the western slopes of the Mount Lofty Ranges and on the central highlands of the Middle North of South Australia. They are developed as a longitudinal belt extending for about 150 miles north of Adelaide. Most of this country lies between the 500 feet and 2,000 feet contours. The physiography has been dealt with by Fenner (1930). In the northern portions of the area the soils are typically developed in a series of wide and roughly parallel valleys which run for considerable distances in a general north and south direction. The soils of this group also extend along the coastal portion of the Mount Lofty Ranges, south of Adelaide. Typical red-brown earths

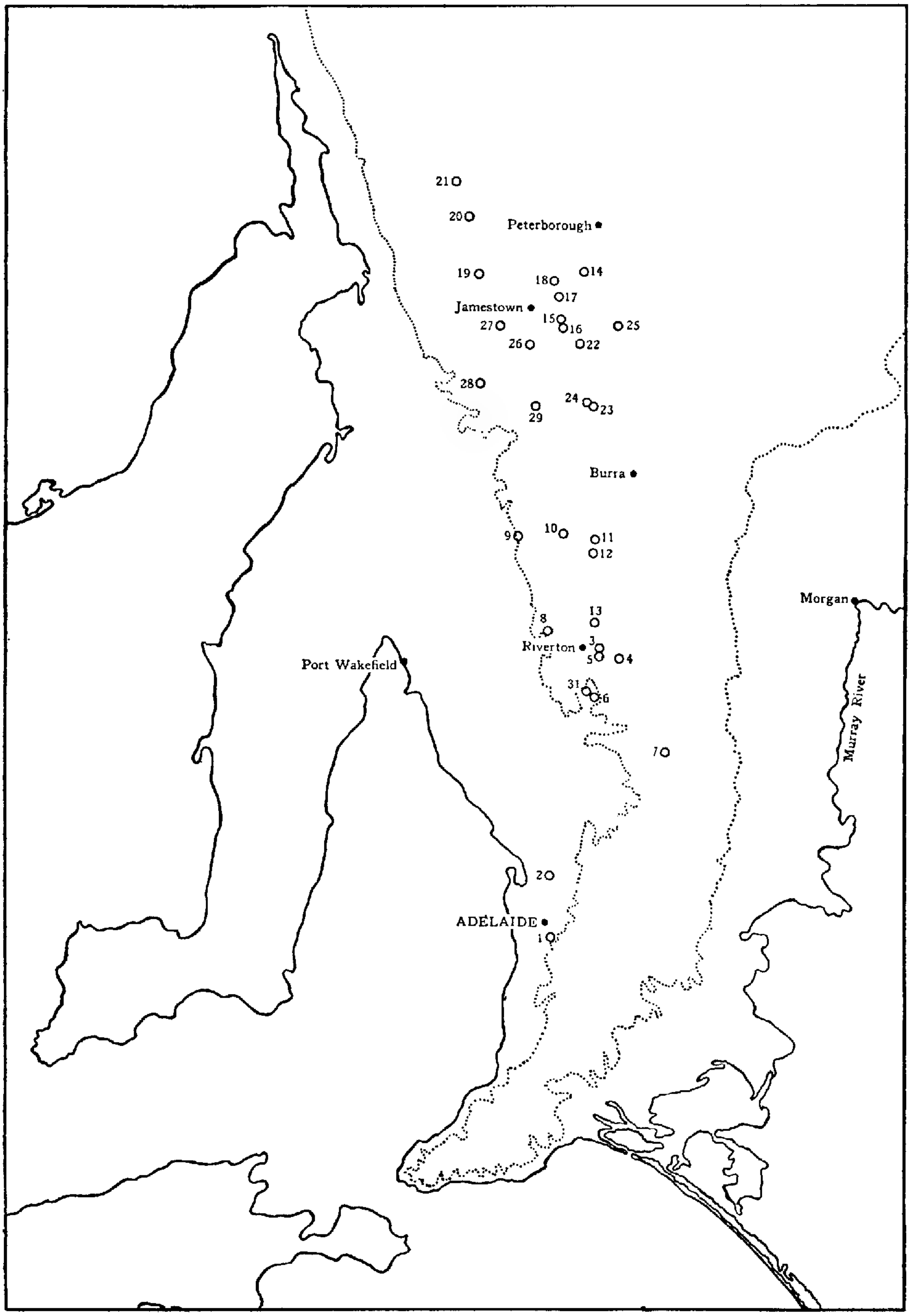

Fig. 1
Map of portion of South Australia, showing the localities from which the soil profiles have been collected. The numbers refer to the profile numbers given in the Appendix. The dotted line represents the 200 metre contour.

are also found on the coastal plain, north of Port Lincoln, but so far no samples from this locality have been examined in the laboratory.

Figure 1 shows the localities from which profiles have been examined, and this gives an indication of the general distribution of the soils throughout the central and middle northern districts of South Australia. For details showing the limits of distribution of the red-brown earths Prescott's Map of the Soils of Australia (1931) may be consulted.

The soils under discussion are typically brownish loams to sandy loams in the surface horizons, becoming redder and heavier with depth. Geologically, they have been developed on Pre-Cambrian shales, slates and schists, or on alluvial deposits derived from these rocks. Where the soils occur on alluvial deposits, as on the plains and in valleys, they are very uniform over large areas and the profiles are deeper than on the rises of undulating country. The geology of the area has been dealt with by Howchin (1918), but his Lower Cambrian Series is now recognised as Pre-Cambrian (Ward 1928). More recent geological information will shortly be published by Segnit.

While red-brown earths normally occur on the shales and slates in this area, grey to greyish-brown soils, related to the rendzinas, frequently develop in places where the parent rock is more highly calcareous. Areas of these grey soils may be surrounded by typical red-brown earths, and some examples of such occurrences are included in Table III of the Appendix to this paper.

The mean annual rainfall throughout the area varies from 16 to 25 inches per annum. The seasonal distribution shows a very marked winter maximum, approximately 75 per cent. of the total falling during the months of April to October. The average rainfall per wet day is greater than that in the Mallee areas, varying from 0·19 to 0·24 inches. The Meyer ratio of precipitation to saturation deficit ranges from 75 to 150. The climatic control of this soil group has been dealt with by Prescott (1934).

The efficiency of leaching of the rainfall is such that well-defined soil horizons have been developed and calcium carbonate has generally been completely removed from the upper part of the profile. However, cyclic salts have not been entirely removed from the region as a whole and there is a tendency for some accumulation to occur, in isolated cases, under favourable topographical conditions.

Ecologically, the red-brown earths are clearly distinguished, on the one hand, from the drier Mallee areas, and, on the other hand, from the sclerophyll forests which occur on the more highly podsolized soils of the Mount Lofty Ranges. The vegetation is typically open savannah woodland, peppermint gum *(Eucalyptus odorata)* being the most prominent tree. Towards the drier northern limits this species frequently develops a mallee habit of growth. However, some of the plains country *(e.g.,* Booborowie Flats) was open grassland in its original state and never carried timber. The surrounding hills carried blue gum *(Eucalyptus leucoxylon)* and she-oak *(Casuarina stricta)*. Around Jamestown the plains originally carried small acacia and peppermint gum with a mallee habit, while the hills were covered with she-oak and tussock grass.

Blue gum *(Eucalyptus leucoxylon)* replaces peppermint gum as the characteristic tree in the wetter portions of the area, while she-oak occurs extensively in the drier regions as well as on the shallower and more stony soils elsewhere. The vegetation has been recently described by Wood (1937).

The experimental farms of the Waite Institute and Booborowie have been established on soils of this group, although experimental work at the latter place was discontinued in 1930. For the response to various fertilizer and cultural treatments, the reports of these centres should be consulted. Statistics showing the average wheat yields over a period of twenty years for each individual hundred have been published by Perkins (1936), and Phipps has summarized the mean yield and its variability for the Agricultural Development Commission (1931).

During 1934 samples representing thirty typical profiles of the red-brown earths were collected throughout the Lower and Middle North of South Australia. Three profiles representing greyish calcareous soils associated with this group were also sampled. In addition to these, four other red-brown earth profiles were available in the Waite Institute soils collection. Altogether thirty-seven profiles, consisting of two hundred and eleven individual samples, have been examined in the laboratory. The localities from which these profiles were collected have already been indicated in figure 1. For permanent reference a more detailed description and the complete analytical data for each profile are recorded in the Appendix to this paper.

II THE WAITE INSTITUTE PROFILE

Since the soils at the Waite Institute are very typical of the red-brown earths, two profiles have been sampled and examined in considerable detail (see Appendix, Table I). At this locality the soil has developed on an alluvial fan from the foothills of the Mount Lofty Ranges and the parent material is derived from the adjacent Pre-Cambrian shales and slates. In one profile (U 69) samples have been collected at each successive inch to a depth of 46 inches, so that the variations in the profile can be very fully followed.

The surface soils have a characteristic brown colour, due to the presence of organic matter in this horizon, but as its amount decreases in the profile the colour of the mineral portion of the soil predominates, gradually changing to a reddish-brown at 12-18 inches and to red in the deep clay.

Although calcium carbonate has not been removed from the lower horizons, the soil is weakly podsolized and eluviation of the clay has occurred. This change in the mechanical composition of the profile is very clearly seen in figure 2. The surface soil consists of a friable loam with a very pronounced fine sand fraction. The proportion of clay decreases somewhat during the first few inches and then gradually increases to a well-defined illuvial zone of heavy clay. The inch by inch profile (U 69) was not sampled below this zone, but the nature of the lower horizons can be seen in the second profile (U 151) which represents a slightly shallower phase, having its clay horizon nearer the surface. Below this illuvial horizon the amount of clay again decreases, and at this point calcium carbonate appears in the profile, having been completely leached from the overlying A and B_1 horizons.

There is a remarkable constancy between the relative proportions of fine sand, coarse sand, and silt throughout the profile, and this is shown graphically in figure 3. The nearly constant proportion of these three fractions, which together

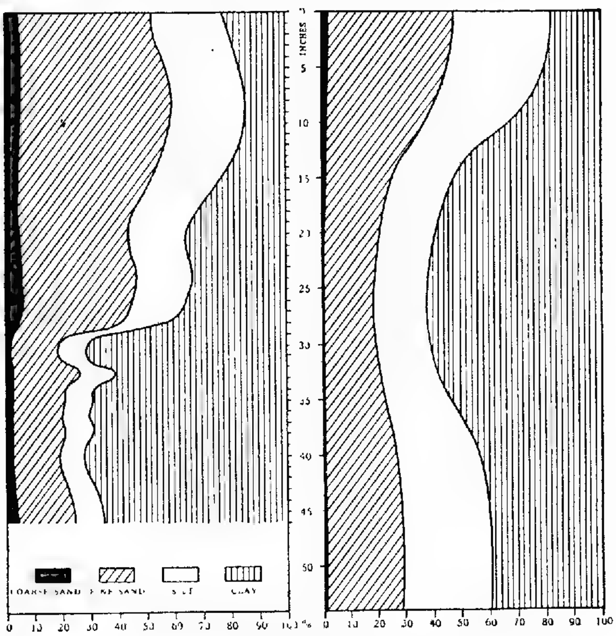

Fig. 2
Illustrating the mechanical composition of two Waite Institute profiles
Left—Profile U 69 U 111, sampled inch by inch
Right—Profile U 151–U 157

constitute the non-colloidal framework of the soil, shows clearly the uniform nature of the original parent material throughout the profile, and it also shows that the changes in the colloidal fraction (clay) of the different horizons has been brought about by a process of eluviation. This accumulation of clay in the B_1 horizon has occurred as a result of its dispersion and mechanical eluviation under the slightly acid conditions existing in the surface soil. An examination of the silica: sesquioxide ratios for profile U 151 shows that there has been only a small amount of leaching of the sesquioxides from the surface layers into the lower horizons. The values for the free ferric oxide in the different parts of the profile (Table I) also show that there has been little actual decomposition of the clay to silica and sesquioxides, as occurs in podsols.

TABLE I

The Humus and Free Iron Oxide Content of a Waite Institute Profile.(1)

Soil No.	Depth	Humus	Free Fe_2O_3
		%	%
U 151	0–4″	1·53	2·14
U 152	4–9″	1·02	2·46
U 153	9–18″	0·59	4·68
U 154	18–27″	0·41	5·17
U 155	27–36″	0·45	4·72
U 156	36–45″	0·34	3·42
U 157	45–54″	0·26	3·34

(1) Determination by Mr. A. B. Beck (unpublished).

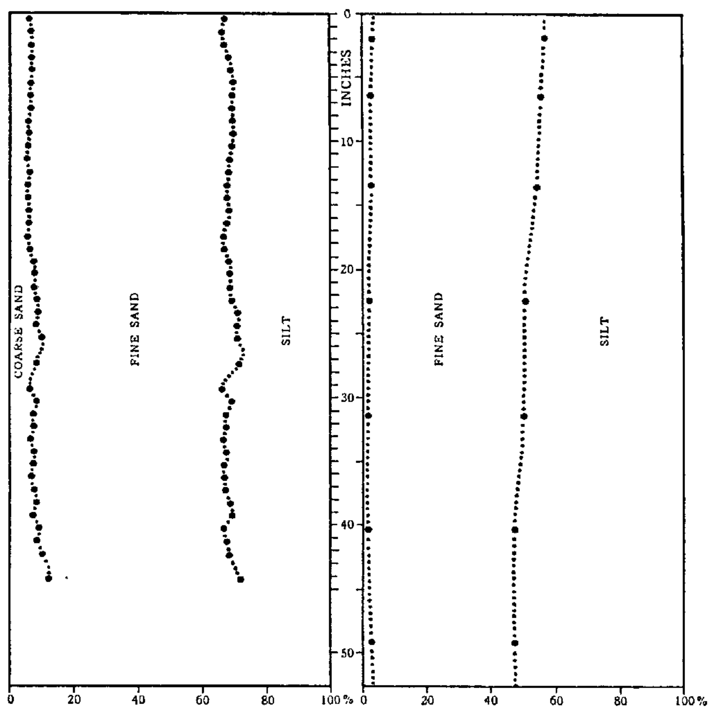

Fig. 3

Illustrating the mechanical composition of the non-colloidal fraction of two Waite Institute profiles. The vertical lines of dots represent the percentage amounts of coarse sand and coarse sand + fine sand, respectively, in the non-colloidal fraction of profiles U 69–U 111 (left) and U 151–U 157 (right).

The amounts of organic carbon and nitrogen decrease progressively throughout the profile, and the carbon: nitrogen ratio changes from about 13 in the surface horizon to a value of 7-8 at a depth. The humus content of U 151 profile has been determined by Mr. A. B. Beck and the values, given in Table I, show a gradual decrease in amount with depth.

The amount of potash extracted by digestion with hydrochloric acid is closely related to the amounts of silt and clay in the profile, and this relationship for the U 69 profile is shown graphically in figure 4. From this diagram it is seen that

$$\% \ K_2O = 0.0155 \times (\text{Clay Percentage} + \tfrac{2}{3} \text{ Silt Percentage}).$$

Although the soils are somewhat unsaturated with bases in the surface horizons, the values ranging from 60 to 65 per cent. of full saturation, the percentage saturation increases progressively with depth and the horizons below the appearance of calcium carbonate are fully base saturated. The corresponding values for soil reaction range from pH 6·0 at the surface to pH 8·6 in the lower horizons. Calcium is the dominant exchangeable base in the surface soil and accounts for the good texture in the field. The proportion of magnesium, how-

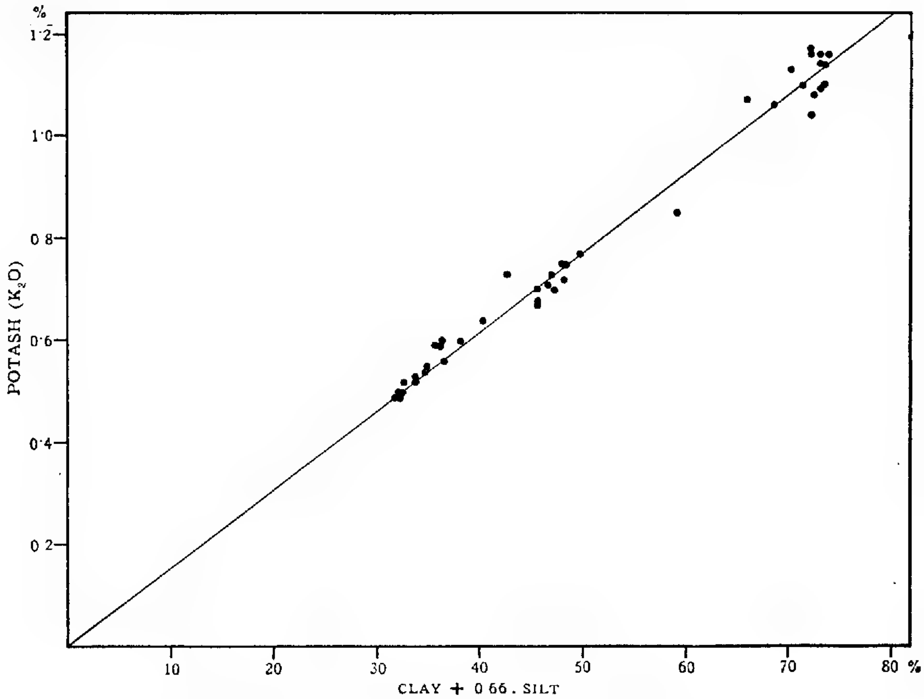

Fig. 4

Illustrating the relationship between the acid soluble potassium and the amounts of clay and silt in the Waite Institute profile U 69–U 111

ever, increases considerably in the subsoil. Exchangeable sodium is low throughout the profile, indicating that the leaching conditions and calcium status of the soil are sufficiently good to remove cyclic salts, without an accumulation of exchangeable sodium.

During the course of other investigations a number of the physical constants have been determined for the Waite Institute soils, and for convenience these values are recorded in Table II. Although the various determinations have been made on samples from different portions of the Waite Institute experimental fields the soil is of sufficient uniformity for comparisons to prove of interest.

Table II.

Some Physical Constants of the Waite Institute Profile.

Depth	Moisture Equivalent [1]	Wilting Point [2]	Sticky Point [3]	Depth	Water Holding Capacity [4]	Apparent Specific Gravity [4]
	%	%	%		%	
0–9″	21·5	6·9	22·6	0–4″	27·3	1·32
9–18″	29·5	17·4	34·8	4–16″	15·8	1·73
18–27″	35·8	21·2	42·7	16–42″	33·3	1·40
27–36″	31·1	17·6	45·6	below 42″	29·8	1·44
36–45″	28·2	14·5	—			
45–54″	28·6	15·5	—			

Moisture Equivalent and Wilting Point on Profile U 158 U 163.
Sticky Point on Profile U 151–U 155.

(1) Determinations by H. G. Poole.
(2) Determinations by E. F. Fricke.
(3) Determinations by B. Johns.
(4) Determinations by A. B. Cashmore (1934).

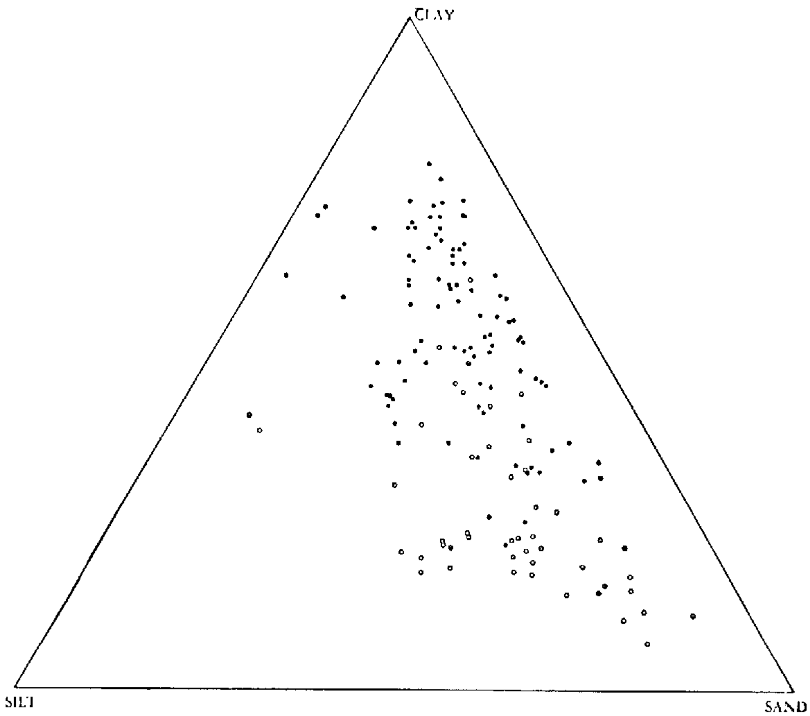

Fig. 5

Distribution triangle illustrating the mechanical composition of all the red-brown earths examined. Open circles represent surface soils, black circles represent subsoils.

III LABORATORY EXAMINATION OF THE SAMPLES

(a) Mechanical Analysis

As already mentioned, the parent material on which the red-brown earths are developed is such as to give rise, naturally, to soils of medium to heavy texture. Since the surface soils are generally neutral to slightly acid in reaction,

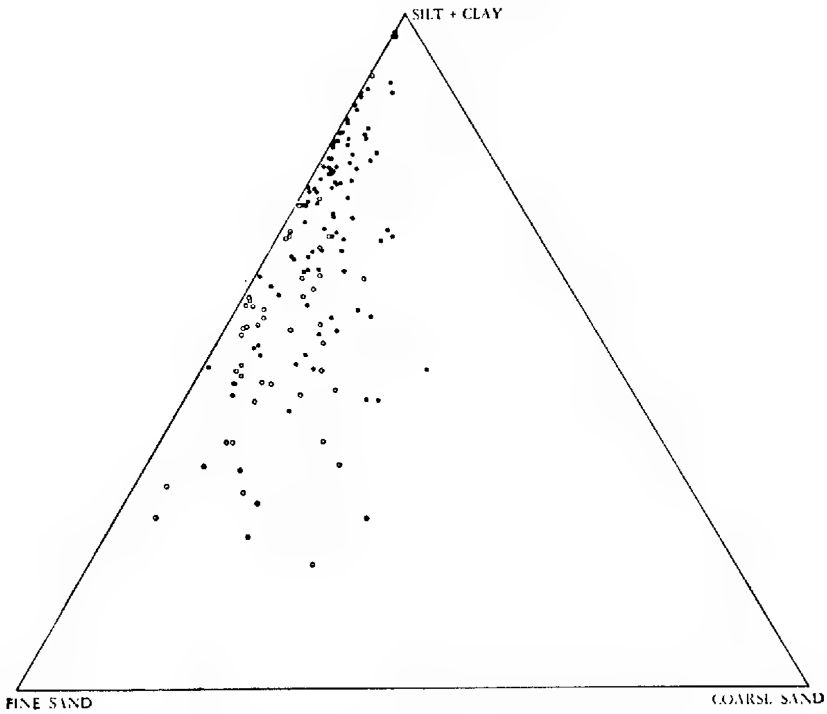

Fig. 6

Distribution triangle illustrating the mechanical composition of all the red-brown earths examined. Open circles represent surface soils, black circles represent subsoils.

some downward leaching of the clay has occurred, resulting in a surface soil of lighter texture overlying a marked zone of clay accumulation in the B_1 horizon. This downward leaching of the clay under neutral to slightly acid conditions is very typical of the group as a whole, although a few profiles have been encountered in which the accumulation of clay has probably resulted from its peptization and greater mobility in the presence of important amounts of exchangeable sodium. Such profiles, however, are not typical and only occur where topographic or climatic conditions have produced an accumulation of soluble salts.

Figure 5 shows graphically, in the usual triangular diagram, the proportions of sand, silt and clay in the red-brown earth profiles examined. It will be seen that the surface soils are generally sandy loams, loams, or clay loams, while the subsoils are much heavier in texture with a very large proportion falling into the heavy clay group. Silt is almost always over 8 per cent. and is generally a characteristic fraction amounting to 10-35 per cent. of the carbonate-free mineral fraction of the soil. In a few profiles, particularly one from the Booborowie Flats (3810-3814), the silt fraction is dominant. In the soils examined, all of the texture classes except sand, sandy clay loam, and sandy clay are represented.

The amounts of coarse sand, fine sand, and silt plus clay are represented graphically in figure 6, and this triangular diagram shows very clearly the high ratio of fine sand to coarse sand. In 60 per cent. of the samples examined this ratio was greater than 3. The mineralogical composition of the parent material, no doubt, accounts for the low amounts of coarse sand in these profiles.

(b) Calcium Carbonate.

The majority of the surface soils of this group are free from calcium carbonate, or contain only very small amounts, owing to the leaching of the carbonate into the lower horizons. The maximum concentration generally occurs in the B_2 horizon, immediately below the zone of clay accumulation. Below this horizon the amount decreases somewhat.

Table III gives the frequency distribution of the calcium carbonate percentages in the series of soils examined, and shows clearly the enrichment of the subsoil.

TABLE III

Frequency Distribution of Calcium Carbonate Percentage in Red-Brown Earth Soils and Subsoils

Calcium Carbonate, %	nil to 0.01	0.01 to 0.1	0.1 to 1.0	1.0 to 2.0	2.0 to 3.0	3.0 to 4.0	4.0 to 5.0	5.0 to 6.0
Surface Soils	25	16	6	1	3	—	—	—
Subsoils	17	20	15	3	5	4	3	2

Calcium Carbonate, %	6.0 to 7.0	7.0 to 8.0	8.0 to 9.0	9.0 to 10.0	10.0 to 20.0	20.0 to 30.0	30.0 to 40.0
Surface Soils	—	—	1	—	—	—	—
Subsoils	3	—	1	2	8	6	4

(c) Reaction

The surface soils of the red-brown earths are slightly acid to slightly alkaline in reaction while, owing to the frequent occurrence of calcium carbonate in the lower horizons, the subsoils are nearly always neutral to alkaline. Most of the surface soils with a reaction greater than pH 7 occur in the more northern areas where, owing to the drier climatic conditions (lower rainfall and higher evaporation), leaching has not been so complete.

The presence of small amounts of exchangeable sodium in the lower horizons of some of the profiles has resulted in values for soil reaction in excess of pH 8·4. In two or three profiles, in which the larger amounts of exchangeable sodium were found, values up to pH 9·6 have been recorded.

All determinations have been made on a 1 : 2·5 water suspension, and the glass electrode was used throughout. Table IV shows the frequency distribution of these soils with respect to hydrogen ion concentration.

TABLE IV

Frequency Distribution of the Reaction of Red-Brown Earth Soils and Subsoils (Glass Electrode)

pH	5.6 to 5.8	5.8 to 6.0	6.0 to 6.2	6.2 to 6.4	6.4 to 6.6	6.6 to 6.8	6.8 to 7.0	7.0 to 7.2	7.2 to 7.4	7.4 to 7.6
Surface Soils	1	2	3	5	2	4	4	3	3	3
Subsoils	—	—	—	1	—	1	2	5	3	1

pH	7.6 to 7.8	7.8 to 8.0	8.0 to 8.2	8.2 to 8.4	8.4 to 8.6	8.6 to 8.8	8.8 to 9.0	9.0 to 9.2	9.2 to 9.4	9.4 to 9.6
Surface Soils	1	3	3	6	4	2	—	1	—	—
Subsoils	8	6	3	5	21	13	12	5	5	4

(d) Nitrogen and Organic Matter

The typical brown colour of the surface soils is due to the effect of organic matter in modifying the red colour of the mineral fraction. The amount, however, is seldom great except in a few profiles. In the latter cases, as a result of an increase in the water supply to the soil, brought about either by underground sources or by the topographical features of undulating country diverting the surface run-off to the lower lying flat areas, there has been an increased growth of vegetation leading to these particular soils containing somewhat higher quantities of organic matter than average.

The amounts of organic carbon and nitrogen present in the surface nine inches have been computed for 33 profiles, for which figures are available and the following are the mean values:—

Organic carbon - -	0·94%
Nitrogen - - -	0·097%

The organic matter decreases rapidly with depth throughout the profile, resulting in a much redder colour in the subsoils. Tables V and VI show the frequency distribution of the percentage of nitrogen and organic carbon, respectively, in the soils and subsoils examined.

TABLE V

Frequency Distribution of Nitrogen Percentage in Red-Brown Earth Soils and Subsoils

Nitrogen, %	0 to .01	.01 to .02	.02 to .03	.03 to .04	.04 to .05	.05 to .06	.06 to .07	.07 to .08	.08 to .09	.09 to .10
Surface Soils	—	1	—	—	3	5	6	4	10	8
Subsoils	—	3	7	16	11	14	12	10	7	2

Nitrogen, %	.10 to .11	.11 to .12	.12 to .13	.13 to .14	.14 to .15	.15 to .16	.16 to .17	.17 to .18	over .18
Surface Soils	9	4	3	3	—	2	—	—	4
Subsoils	1	—	—	—	—	—	—	—	—

TABLE VI

Frequency Distribution of Organic Carbon Percentage in Red-Brown Earth Soils and Subsoils

Organic Carbon, %	0 to 0.1	0.1 to 0.2	0.2 to 0.3	0.3 to 0.4	0.4 to 0.5	0.5 to 0.6	0.6 to 0.7	0.7 to 0.8	0.8 to 0.9	0.9 to 1.0
Surface Soils	—	—	—	5	2	6	7	8	5	4
Subsoils	3	13	17	13	13	10	8	4	—	2

Organic Carbon, %	1.0 to 1.1	1.1 to 1.2	1.2 to 1.3	1.3 to 1.4	1.4 to 1.5	1.5 to 1.6	1.6 to 1.7	1.7 to 1.8	over 1.8
Surface Soils	8	2	3	1	4	1	—	1	4
Subsoils	—	—	—	—	—	—	—	—	—

The carbon: nitrogen ratio varies within wide limits, as is seen in figure 7. The ratio becomes narrower with depth, and a number of subsoils show values less than 5: 1. For the majority of the surface soils to a depth of 9 inches the ratio lies between 12: 1 and 8: 1.

The continued cultivation of these soils for cereal production under the older rotations, in which a period of bare fallow alternates with one of crop, must inevitably lead to a serious decline in the organic matter reserves. No quantitative data bearing on this question are available, but the consensus of opinion among farmers who have cultivated these soils for long periods is that it is becoming increasingly more difficult to secure a good tilth during cultivation. From this it would appear that the reserves of organic matter are already being depleted.

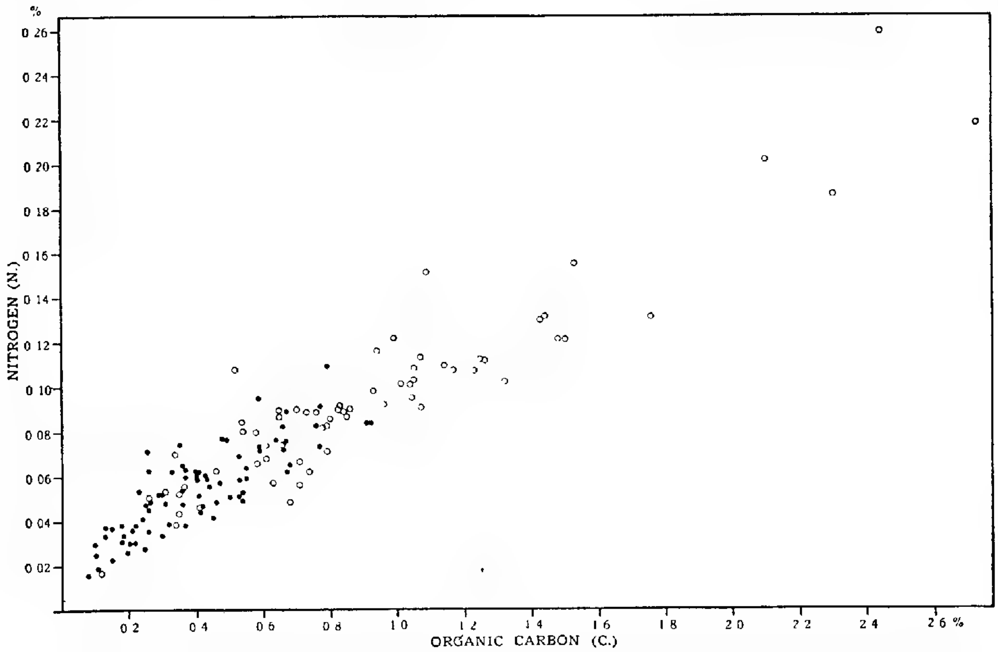

Fig. 7
Illustrating the relationship between the organic carbon and the nitrogen contents of the red-brown earths. Open circles represent surface soils, black circles represent subsoils.

In order to maintain the fertility and to improve the mechanical condition of these soils the organic matter content should be built up. A system of rotation which includes a period under pasture is highly desirable.

(e) Potash and Phosphoric Acid

Only potash and phosphoric acid have been determined in the hydrochloric acid extracts of these soils. All the soils examined are well supplied with potash, amounts above 0·5% K_2O being general in the surface soils. Larger amounts are present in the subsoils. While the correlation between the clay and silt content of the soil and the amount of potash does not hold so closely for this group of soils as it does for the Waite Institute profile, the same general relationship is noticeable and the percentage of potash ranges from 0·015 to 0·029 × (Clay Percentage + $\frac{2}{3}$ Silt Percentage). From the values for exchangeable potassium, which are given in another section, it will be seen that the soils are well supplied with this element in a readily available form.

Phosphoric acid generally ranges from 0·03 to 0·07 per cent. in the surface soils, with somewhat smaller amounts in the subsoils. It will be noted that these soils contain distinctly more phosphoric acid than do the mallee soils, the latter seldom exceeding 0·03 to 0·04 per cent.

Table VII illustrates the frequency distribution of the potash and phosphoric acid contents of these soils, while the individual values are tabulated in the Appendix.

TABLE VII

Frequency Distribution of the Acid Soluble Potassium and Phosphoric Acid in Red-Brown Earth Soils and Subsoils

Potash (K_2O) - %	0 to 0.20	0.21 to 0.40	0.41 to 0.60	0.61 to 0.80	0.81 to 1.00	1.01 to 1.20	1.21 to 1.40	1.41 to 1.60	1.61 to 1.80	1.81 to 2.00	2.01 to 2.20
Surface Soils	—	2	8	13	12	7	3	2	—	—	—
Subsoils -	—	—	—	1	14	17	15	6	3	2	1

Phosphoric Acid (P_2O_5) - %	0 to 0.01	0.01 to 0.02	0.02 to 0.03	0.03 to 0.04	0.04 to 0.05	0.05 to 0.06	0.06 to 0.07	0.07 to 0.08	0.08 to 0.09	0.09 to 0.10	0.10 to 0.11
Surface Soils	—	—	4	9	20	11	9	3	2	1	—
Subsoils -	—	1	9	16	9	6	2	3	—	—	1

Two profiles (3778-3781 and 3782-3784), collected in the Hundred of Belalie, show the relatively high phosphoric acid content of 0·16 to 0·18 per cent. P_2O_5. Although these particular soils occur in association with the red-brown earths, they do not belong to the group, having been developed on a highly calcareous parent material. The soils are greyish-brown in colour and contain considerable amounts of calcium carbonate in all horizons. In view of the higher phosphoric acid content of these soils, it is interesting to note that Jack (1919) has reported the occurrence of small phosphate deposits, in a formation of a similar description, seven miles to the north of this locality.

(f) Reactive Manganic Oxide

The amount of manganese brought into solution by leaching with a normal solution of ammonium acetate, adjusted to pH 7 and containing 0·2 per cent. of hydroquinone, has been determined for one complete profile (U 151) and for the surface soils of the remainder. According to Leeper (1934) this gives a measure of the reactive forms of manganese, which may be considered to be readily available to plants. The high values obtained, typical surface soils ranging from 160 to 750 parts of manganese per million parts of soil, indicate that these soils are very well supplied with manganese. The mean value for 32 soils was 345 p.p.m. In the few cases in which the amounts of exchangeable manganese and manganic oxide were determined separately it was found that by far the larger portion of the manganese occurred in the oxidized form. Exchangeable manganese was absent in the alkaline subsoils, the reactive manganese existing in these entirely as oxide. Evidence of the occurrence of reactive manganic oxide in these soils is also furnished by the rapid drift which occurs when attempts are made to measure their reaction by the quinhydrone electrode.

In the Waite Institute profile (U 151) the reactive manganic oxide decreases steadily from its maximum concentration of 430 p.p.m. in the surface horizon to a minimum of 110 p.p.m. in the B_1 horizon. It then begins to increase again, reaching 230 p.p.m. at the lowest depth sampled. Since manganese is most mobile as the manganous ion, it would appear that its concentration in the surface horizon is connected with the more oxidizing conditions in this layer bringing about its precipitation as oxide.

(g) Soluble Salts

Accumulations of soluble salts are not frequent in the soils of this group, although occasionally, where such factors as topography and drainage have led to their concentration, some difficulties have been experienced. In the samples examined chlorides only have been determined, and the results are expressed as sodium chloride. At a few localities appreciable amounts of chlorides were present in the lowest depth sampled, but only in three profiles did the total sodium chloride content of the top 36 inches of soil exceed 0·10 per cent.

In order that a comparison may be made with the results published for South Australian and West Australian mallee soils, the amounts of sodium chloride present in the top 24 inches of soil have been computed for 31 profiles and the values are set out in the form of a frequency table (Table VIII). From this table it will be seen that the majority of profiles contain less than 0·02 per cent. of sodium chloride in the top two feet of soil, and the mean value of all the profiles examined is 0·025 per cent.

(h) Exchangeable Bases

The exchangeable bases have been determined in twenty-three profiles and the individual results are tabulated in the Appendix. The values for seven typical profiles, including that from the Waite Institute, which has been examined in considerable detail, are represented graphically in figure 8. It will be seen that calcium is the most important of the exchangeable bases in the surface horizons, but appreciable amounts of magnesium occur, as is so frequently the case in Australian soils. The proportion of magnesium increases with depth, and in

TABLE VIII

Frequency Distribution of the Sodium Chloride Content of Red-Brown Earth Profiles to a depth of Twenty-four Inches

Sodium Chloride %	0 to 0.01	0.01 to 0.02	0.02 to 0.03	0.03 to 0.04	0.04 to 0.05	0.05 to 0.06	0.06 to 0.07	0.07 to 0.08	0.08 to 0.09	over 0.09
Number of Sites	4	17	5	1	1	—	—	1	1	1

many of the subsoils it even exceeds the calcium in amount. Significant amounts of exchangeable sodium are also present in certain of the subsoils, especially where soluble salts in excess of the average occur. As already mentioned, valuable amounts of exchangeable potassium occur in all of these soils and the proportion is highest in the surface soils, probably as the result of the enrichment by plant residues.

As a check on the values for total exchangeable bases, the amounts of ammonium absorbed by the soils, after leaching with a normal solution of ammonium chloride, were determined for a number of samples, and the values so obtained agreed very well with the sum of the individual bases displaced. For the thirty soils for which figures are available the mean amount of ammonium absorbed was 16·05 milligram equivalents per 100 grm. of soil, and the corresponding values for the total exchangeable bases was 16·85 milligram equivalents.

The mean values for the percentage composition of the exchangeable bases in the surface, subsurface and subsoils of twenty-two red-brown earth profiles are presented in Table IX. For comparison the corresponding values are given for nine South Australian mallee profiles.

TABLE IX

The Average Percentage Composition of the Exchangeable Bases in Red-Brown Earth and Mallee Profiles

	Surface				Intermediate				Subsoil			
	Ca	Mg	K	Na	Ca	Mg	K	Na	Ca	Mg	K	Na
Red-Brown Earths .... (22 Profiles)	61	24	11	4	52	33	8	7	44	41	6	9
Mallee Soils .... (9 Profiles)	63	25	7	5	41	35	7	17	27	37	10	26

Average Percentage Base Saturation

	Surface.	Intermediate.	Subsoil.
Red-Brown Earths .... (22 Profiles)	78	84	95

Surface soils represent samples to approximately 9"
Subsoils represent samples below about 15"

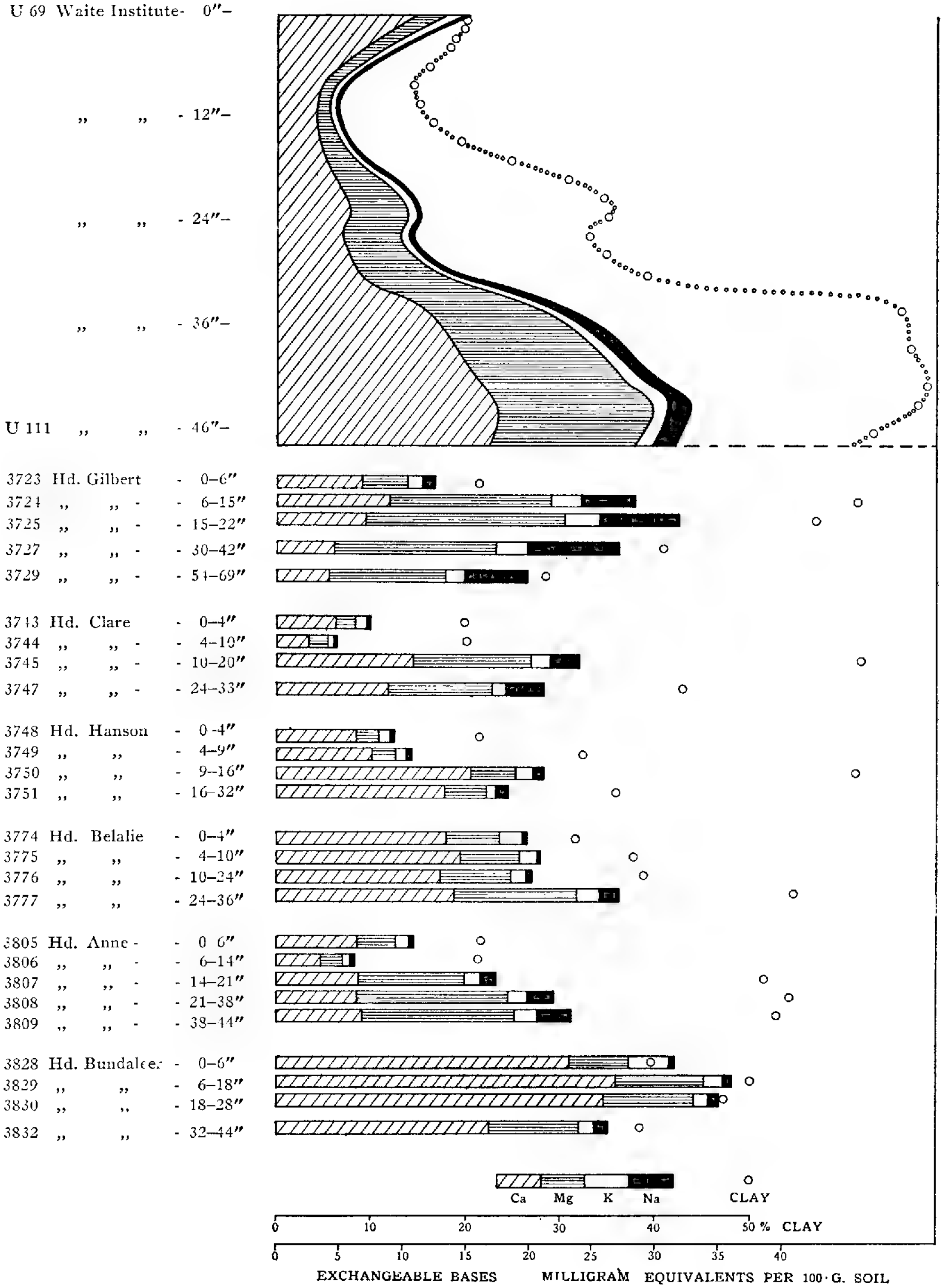

Fig. 8

Illustrating graphically the exchangeable bases in seven representative red-brown earth profiles. The amounts of clay are also indicated by means of the open circles.

It will be noticed that the red-brown earths are significantly lower than the mallee soils in exchangeable sodium, especially in the deeper horizons of the profile. With the exception of the Parafield profile (3694-3699) which, on account of impeded drainage, cannot be regarded as normal, the exchangeable sodium in the subsoils of the red-brown earths never attains the average value for the mallee subsoils. Calcium and magnesium occur in about the same proportion in the surface soils of both the above groups. However, while the proportion of magnesium increases at approximately the same rate throughout the profiles of both groups, the proportion of calcium does not decrease so rapidly in the red-brown earths as it does in the mallee soils.

Exchangeable hydrogen has also been determined in these soils in order to obtain a measure of their base exchange capacity and percentage base saturation.

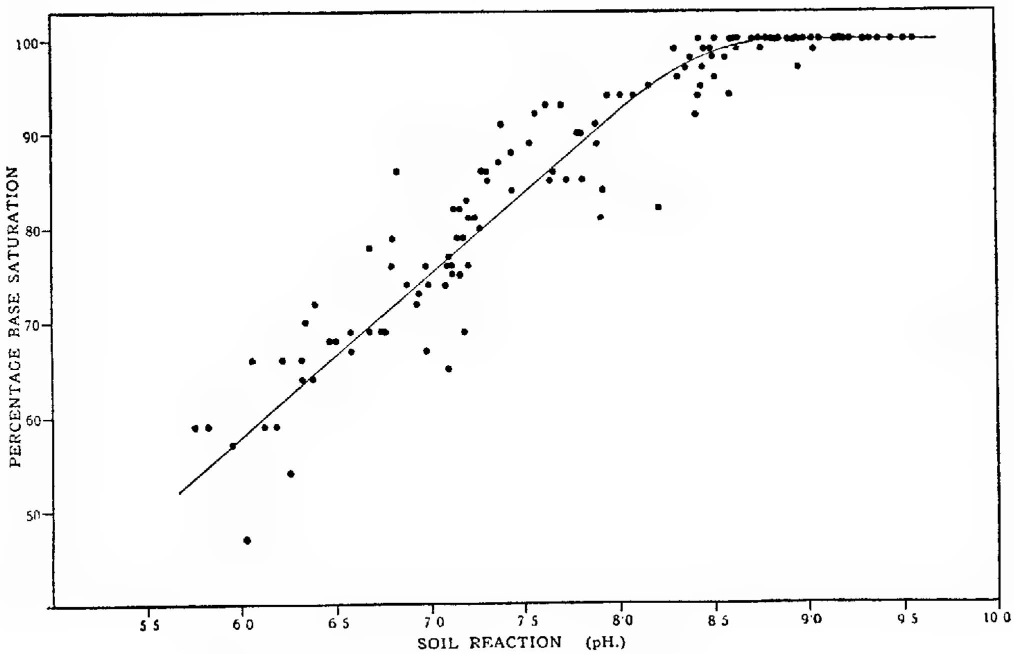

Fig. 9

Illustrating the relationship between the soil reaction and the percentage base saturation of the red-brown earths

The mean values for the twenty-two profiles are included in Table IX. These figures show the slightly podsolized nature of the surface horizons, while the subsoils tend towards full base saturation. The general relationship between soil reaction and percentage base saturation is shown in figure 9.

By means of graphical methods, the contribution of the clay and organic matter to the total base exchange capacity of the soil has been determined for each profile. The values so obtained show that the base exchange capacity varies in the different profiles from 0·39 to 0·61 milligram equivalents per grm. of clay, while the soil organic matter has a base exchange capacity ranging from 2·2 to

6·1 milligram equivalents per grm. of carbon (Table X). Figure 10 shows graphically this relationship between base exchange capacity and the amounts of clay and organic matter. In the left-hand portion of the diagram the actual base exchange capacity of the soil has been plotted against the calculated base exchange capacity due to clay and organic carbon, using the values deduced for each profile as given in Table X. In the right-hand portion of the figure the same relationship has been plotted by using the mean values for the base exchange capacity of the clay and organic matter, namely, 0·48 milligram equivalents per grm. of clay and 3·8 milligram equivalents per grm. of organic carbon.

TABLE X

The Base Exchange Capacity of Clay and Organic Matter in various Red-Brown Earth Profiles

Profile No.	Base Exch. Cap. m.e. per grm. Clay	Base Exch. Cap. m.e. per grm. Carbon
U 69 –U 111	0.40	4.0
U 151–U 157	0.47	2.9
3694–3699	0.41	5.3
3714–3717	0.61	3.7
3723–3729	0.54	3.2
3734–3738	0.48	2.9
3743–3747	0.43	2.2
3748–3752	0.39	3.1
3757–3761	0.44	3.1
3762–3766	0.43	3.5
3770–3773	0.44	2.2
3774–3777	0.49	5.9
3797–3800	0.61	6.1
3801–3804	0.45	3.6
3805–3809	0.40	3.6
3810–3814	0.51	3.6
3819–3823	0.47	3.8
3824–3827	0.57	4.6
3828–3832	0.61	6.1
1854–1857	0.41	2.8
Average for 20 profiles ...	0.48	3.8
Range	0.39 to 0.61	2.2 to 6.1

m.e. = milligram equivalents

An examination of the values for the base exchange capacity of the clay fraction of the red-brown earths shows only a general correlation with the silica: alumina or the silica: sesquioxide ratio of the clay. The more siliceous clays tend to have the greater base exchange capacity. This latter is apparently influenced by other factors in addition to the above, and in this respect it is considered that the "International Clay" fraction includes too wide a group of particles. Since base exchange is a surface phenomenon, the smaller particles in the fraction would tend to contribute more to the total effect than would the larger particles. A better correlation would probably be obtained with a fraction of a smaller diameter than "International Clay."

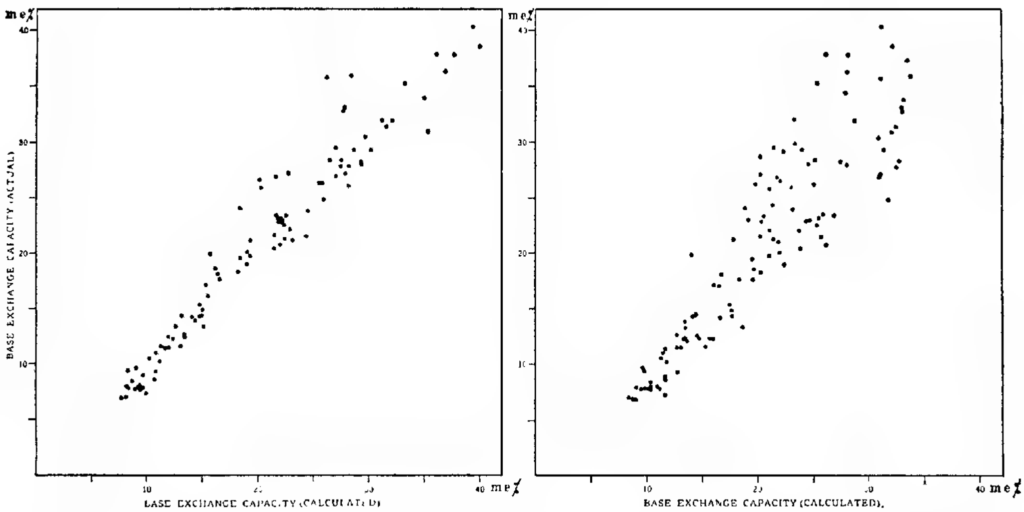

Fig. 10

Illustrating the relationship between the base exchange capacity and the amounts of clay and organic carbon in twenty red-brown earth profiles.

In the left-hand portion of the diagram the actual base exchange capacity has been plotted against the base exchange capacities due to clay and organic matter, using the appropriate values given in Table X for each separate profile. In the right-hand portion the average values for clay and organic matter, namely, 0·48 m.e. per grm. of clay and 3·8 m.e. per grm. of organic carbon, have been used for all the soils.

(i) Composition of the Clay Fraction

A clay fraction with a maximum settling velocity of 0·0001 cm. per second (corresponding to the former "British Clay") was separated from each sample of fifteen typical profiles and silica, alumina and ferric oxide were determined. Table XI shows the frequency distribution of the silica: alumina and silica: sesquioxide ratios in the soils examined. In general these ratios decrease from the surface horizons to the B_1 horizon of clay accumulation, at which part of the profile a small enrichment of sequioxides has occurred and the minimum ratios are reached. In every case the ratios again become wider as soon as the calcium carbonate horizon is reached.

TABLE XI

Frequency Distribution of the Silica : Alumina Ratio and Silica : Sesquioxide Ratio in the Clay Fractions separated from Red-Brown Earth Profiles

$\frac{SiO_2}{Al_2O_3}$ ratio	2.81 to 2.90	2.91 to 3.00	3.01 to 3.10	3.11 to 3.20	3.21 to 3.30	3.31 to 3.40	3.41 to 3.50	3.51 to 3.60	3.61 to 3.70	3.71 to 3.80
A Horizon	—	—	5	2	5	3	6	1	2	—
B_1 Horizon	5	6	2	5	2	1	1	2	—	—
B_2 to C Horizons	—	3	1	5	1	5	3	6	1	3

$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$ ratio	2.01 to 2.10	2.11 to 2.20	2.21 to 2.30	2.31 to 2.40	2.41 to 2.50	2.51 to 2.60	2.61 to 2.70	2.71 to 2.80	2.81 to 2.90	2.91 to 3.00
A Horizon	—	1	—	4	2	5	9	2	1	—
B_1 Horizon	1	4	1	7	5	3	—	—	1	—
B_2 to C Horizons	—	1	—	3	5	4	6	5	4	2

IV THE POSITION OF THE RED-BROWN EARTHS IN THE WORLD CLASSIFICATION

At the present time it is not possible to define clearly the position of the red-brown earths in the World-Group classification of soils. They appear to have certain affinities with the Mediterranean red earths (terra rossa) and the brown earths of northern Europe, but it is probable that they will be found to correspond more closely with the former than the latter when further comparisons can be made. This resemblance to the Mediterranean type would be expected from a consideration of the climatic conditions, the South Australian red-brown earths being developed in a zone of winter rainfall and summer drought. The occurrence of rendzinas on the more calcareous parent materials throughout this zone also suggests a further similarity with the soils of southern Europe, where the terra rossa is associated with the development of rendzinas on the soft limestones. Like the Mediterranean red earths, the South Australian red-brown earths are typically slightly unsaturated in the surface layers and contain calcium carbonate in the lower horizons. Unfortunately, owing to the paucity of good published descriptions of representative red earth profiles, a more detailed comparison cannot be made at present.

The red-brown earths are formed under open savannah woodland, the climatic conditions being favourable to moderate leaching. The humus, although low in amount, is well distributed throughout the top soil and shows no tendency to accumulate either as a peaty surface layer or in the B horizon, as in podsols. The soils are formed under conditions of free drainage.

The red-brown earths differ from the brown earths in that they show a marked accumulation of clay in the B_1 horizon, while calcium carbonate occurs in the B_2 and lower horizons. In this accumulation of clay the red-brown earths show evidence of slight podsolization which may be the result of a smaller return of bases to the surface soil than occurs under deciduous forest—the typical vegetation of the brown earth zone of northern Europe. Although mechanical eluviation of the clay has occurred under the slightly acid conditions prevailing in the surface soil, the free sesquioxides, which are present in small amounts, have not been leached out of the surface horizon to any great extent. In spite of the evidence of incipient podsolization in the surface horizons, the red-brown earths are more basic than the brown earths in the lower horizons owing to the presence of calcium carbonate.

The silica : alumina and silica : sesquioxide ratios of the clay fractions of the red-brown earths differ significantly from those of the podsols, corresponding more closely with those of the brown earths and the terra rossa soils. A marked decrease in the ratios on passing from the A to the B horizon, which is so characteristic of podsols, is not observed in the red-brown earth profiles examined. Although the ratio decreases slightly on passing from the A to the B_1 horizon, it gradually widens again to equal or surpass that of the surface soil. According to Robinson (1936) typical brown earth profiles are characterised by a fairly constant silica : sesquioxide ratio down the profile, with a value generally approximating to 2. This value is somewhat lower than that commonly found for the present soils. Figures for the silica : sesquioxide ratio of the clay throughout terra rossa profiles are not available, but the average value of 2·43 reported by Reifenberg (1933) for surface soils agrees well with that found for red-brown earths in the present investigation.

The red-brown earths differ in many respects from the South Australian mallee soils. Texturally the former are heavier and contain important proportions of silt. Mallee soils are more alkaline than the red-brown earths, calcium carbonate generally being present in the surface of all but the sandier types of the mallee group. The organic carbon, nitrogen, and phosphoric acid status is also lower in the mallee soils, while the soluble salt content of the latter is greater. The important differences in the exchangeable bases of these two soil types have already been discussed. Another significant difference seems to be in the reactive manganic oxide content of the surface soils of the two groups. The amounts present in the red-brown earths are very much higher than in the heavier type of mallee soils, while the mallee sands are much lower again.

V AGRICULTURAL PROBLEMS ASSOCIATED WITH THE RED-BROWN EARTHS

Although these soils as a group are among the most fertile of the South Australian wheat-growing soils, certain difficulties have arisen in limited areas. Perhaps the most important is the phenomenon of "setting" after rain, exhibited by a few soils of this type. When this is severe the top layer of the surface soil runs together and sets to a hard compact crust when it dries out. This crust is about half an inch thick and, under unfavourable weather conditions the germinating wheat plants are often unable to force their way through it. This leads to an uneven germination of the crop. The badly affected areas are irregular in shape and occur scattered throughout the more normal soils. They are always noticeably redder in colour than the normal soils because of their lower content of organic matter.

In one example investigated near Riverton (Soil Nos. 3701-3708) the surface soil of the setting type appeared to correspond to a B horizon. Its clay content was somewhat greater than the normal phase, but the exchangeable sodium was particularly high for a surface soil and constituted 26 per cent. of the total bases. The corresponding value for the exchangeable sodium in the adjoining normal soil was only 2 per cent. The "setting" soil was also much lower in organic matter. The occurrence of the B horizon at the surface suggests that these soils may have resulted from the loss of the surface layers by sheet erosion.

The most successful treatment of this condition would probably lie in the building up of the organic matter content of the soil by a suitable system of crop rotation and green manuring. Applications of gypsum should also assist in reducing the proportion of exchangeable sodium and so improving the physical properties of the soil. However, the effect of the increased organic matter would probably be the more important since, in addition to its direct effect on the soil tilth, it would also increase the biological activity in the soil. The carbon dioxide produced as a result of this increased biological activity would assist in the replacement of exchangeable sodium by calcium. The areas of "setting soils" are slowly extending, due to the depletion of the soil organic matter as a result of the crop rotations practised.

A second problem, also of limited importance, is the local development of salt patches, where the topography is such that the soluble salts tend to accumulate at the surface. A few such patches were seen, near Riverton, irregularly distributed over some gently sloping country. Under a bare fallow crop rotation the area of these patches gradually increases. This extension can be checked, and the salt concentration of the surface soil reduced, by maintaining a grass cover on the land, so decreasing the actual evaporation from the surface soil. If kept under pasture for a period of years, the salt gradually leaches to the lower soil horizons, under the influence of the winter rainfall. However, even when the salt concentration is decreased, the composition of the exchangeable bases is altered and the proportion of sodium increases. This change in the composition of the bases adversely affects the soil texture. Here again the use of gypsum and a system of rotation that increases the organic matter in the soil should be beneficial.

VI NOTES ON THE ANALYTICAL METHODS USED

The analytical methods used were those published elsewhere (Prescott and Piper, 1928, and Piper and Poole, 1929), although many recent and unpublished improvements have been adopted. The fractions separated in the mechanical analysis were those adopted internationally.

The clay fraction separated for silicate analysis corresponded to the former British clay fraction and had a settling velocity of 10^{-4} cm. per second. Silica was determined in this separate by the standard methods of rock analysis involving fusion, double evaporation, ignition and purification by hydrofluoric acid. Titanium was determined colorimetrically in an aliquot of the filtrate, iron and titanium in another aliquot by precipitation with cupferron, while aluminium, iron, and titanium were determined in a third portion by precipitation with ammonia.

Organic carbon was determined gravimetrically by dry combustion. When carbonates were present in the soil they were removed in a preliminary treatment with sulphurous acid. Chlorides were determined by electrometric titration (Best, 1929). The glass electrode was used for all pH measurements.

The exchangeable bases were obtained by leaching the soils with ammonium chloride. Calcium was precipitated as oxalate, magnesium as phosphate or 8-hydroxyquinolate, potassium as perchlorate and sodium as a complex uranyl magnesium acetate. When calcium carbonate was present, it was necessary to determine exchangeable calcium and magnesium in sodium chloride extracts by a slight modification of the method of Hissink (1923). The method of de'Sigmond and Iyengar (1935) was tried, but was found to give erroneous results. Exchangeable hydrogen was determined by the *m*-nitrophenol method (Piper, 1936), and reactive manganic oxide by extraction with ammonium acetate and quinol at pH 7 (Leeper, 1934).

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APPENDIX

LOCALITY AND DESCRIPTION OF THE SOIL PROFILES

1.† HUNDRED OF ADELAIDE. Sections 268 and 250.

U 69 – U 111* These samples represent a typical profile from No. 1 Experimental Field at the Waite Institute, the profile being sampled in inch layers to a depth of 46 inches. The surface soil consists of brown loam or fine sandy loam and overlies a reddish brown clay loam to clay with heavy red clay at a greater depth. Calcium carbonate occured below the depth sampled.

U 151 – U 157 This profile was taken from another Experimental Field about ½ miles west of the first profile.

U 151	0–4″	brown loam.
U 152	4–9″	brown loam.
U 153	9–18″	brown to reddish-brown medium clay.
U 154	18–27″	reddish-brown heavy clay.
U 155	27–36″	reddish-brown heavy clay.
U 156	36–45″	brown medium clay with calcium carbonate appearing.
U 157	45–54″	brown to reddish-brown clay with calcium carbonate continuing.

2. HUNDRED OF YATALA. Section 2186. Near west corner of Parafield Aerodrome.

3694*	0–4″	brown loam.
3695	4–9″	brown loam.
3696	9–13″	brown heavy clay.
3697	13–21″	reddish brown heavy clay (very sticky).
—	21–22″	calcareous hardpan.
3698	22–30″	red-brown heavy clay with soft calcareous rubble.
3699	30–41″	red-brown heavy clay with light rubble (calcareous).

† These numbers correspond with the locality numbers on the map (fig. 1). * Sample number.

3. HUNDRED OF GILBERT. Section 12. 3 miles north-east of Riverton.

This profile represents a soil which is noted for the manner in which it runs together and sets on the surface after rain. This setting is so severe that, at times, germinating wheat seedlings are unable to force their way through the surface crust. These areas subject to severe setting occur in irregular patches throughout the more normal soil.

3704	0–1″	red clay loam.
3701	0–4″	red medium clay.
3702	4–12″	reddish-brown heavy clay with light marl.
3703	12–18″	reddish-brown calcareous loam with light calcareous rubble.

Another profile, collected 30 yards away from the above, represents the normal soil type, which is darker in colour and more friable.

3705	0–6″	dark red-brown friable clay loam.
3706	6–18″	brown to reddish-brown medium clay with small amount of limestone rubble appearing at 15″.
3707	18–36″	reddish-brown medium clay with light nodular limestone rubble.
3708	36–42″	reddish-brown medium clay with small amount of limestone rubble.

4. HUNDRED OF GILBERT. Section 1157. 2½ miles S.S.W. of Marrabel.

This profile represents the lighter soils in the valley of the River Light.

3709	0–5″	grey-brown sand to sandy loam.
3710	5–14″	light brown sandy loam.
3711	14–27″	yellowish-brown sandy clay mottled with red.
3712	27–36″	yellowish-brown sandy clay.
3713	36–42″	yellowish-brown sandy clay.

5. HUNDRED OF GILBERT. Section 504. 2¾ miles east of Riverton.

This profile represents an area that was said to have been badly affected by salt 40 years ago. Although this condition was considerably improved about 12 years ago the trouble has recently recurred.

3714	0–6″	brown medium clay.
3715	6–12″	brown heavy clay.
3716	12–25″	brown heavy clay with calcium carbonate appearing at 25″.
3717	25–42″	brown to reddish-brown heavy clay with marl.

6. HUNDRED OF GILBERT. Section 279. Adjacent to main road, ¼ mile south-east of Tarlee.

3723	0–6″	brown to reddish-brown loam or clay loam.
3724	6–15″	reddish-brown heavy clay.
3725	15–22″	reddish-brown heavy clay.
3726	22–30″	reddish-brown heavy clay with marl.
3727	30–42″	reddish brown heavy clay with marl.
3728	42–54″	reddish-brown medium clay with marl.
3729	54–69″	reddish-brown light clay with small amount of waterworn quartz gravel. Clay and marl continuing.

7. HUNDRED OF BELVIDERE. Section 2996. About 1 mile west of Stockwell.

3730	0–6″	brown fine sandy loam, inclined to set after rain.
3731	6–16″	brown fine sandy loam.
3733	16–24″	reddish-brown light clay.
3732	24–36″	reddish-brown heavy clay.

A section in an adjacent creek showed a depth of over 25 feet of soil. There were four clearly defined bands of clay concentration in the subsoil, and also a layer of waterworn pebbles at 12 feet.

8. HUNDRED OF ALMA. Section 211. On the main Riverton-Balaklava Road, 200 yards east of the River Wakefield road crossing.

3734	0–4″	brown to reddish-brown fine sandy loam.
3735	4–9″	brown to reddish-brown fine sandy loam or loam.
3736	9–18″	dark reddish-brown heavy clay.
3737	18–21″	dark reddish-brown heavy clay.
3738	21–36″	reddish-brown heavy clay with light marl appearing at 21″ and increasing slightly with depth.

9. HUNDRED OF BLYTH. Sections 192, 193. 2½ miles east of Blyth, on main Blyth-Clare road.

This profile is close to the western boundary of the red-brown earths at this locality and was taken in gently undulating country ½ mile west of the foothills. Nearer Blyth mallee soils predominate.

3739	0–7″	dark brown loam with patches of reddish-brown at 5-7″.
3740	7–14″	brown clay loam with calcium carbonate throughout.
3741	14–30″	light brown loam with calcium carbonate increasing.
3742	30–42″	light brown clay loam with marl and calcareous rubble increasing.

10. HUNDRED OF CLARE. Section 515. 4 miles east of Clare.

This profile is typical of the gently undulating country slightly above the flats of the Hill River.

3743	0–4½″	brown loam to clay loam with ironstone gravel appearing at 4″.
3744	4½–10″	light brown loam to clay loam with small amount of ironstone gravel.
3745	10–20″	reddish-brown heavy clay.
3746	20–24″	brown heavy clay with calcium carbonate appearing.
3747	24–33″	brown heavy clay with marl and light calcareous rubble increasing.

11. HUNDRED OF HANSON. Section 432. ½ mile south of Farrell's Flat, at the junction of the Black Springs and Merildin Roads.

3748	0–4½″	brown to reddish-brown loam.
3749	4½–9″	brown to reddish-brown clay loam.
3750	9–16″	reddish-brown heavy clay.
3751	16–32″	reddish-brown heavy clay with marl and calcareous rubble. Heavy rubble at 21-27″.
3752	32–40″	reddish-brown light clay with marl and pockets of decomposed rock stained yellow and red.

12. HUNDRED OF STANLEY. Section 290. 1 mile north of Merildin.

This profile represents the flats in gently undulating country.

3753	0–4″	brown heavy clay.
3754	4–14″	brown to greyish-brown heavy clay with a small amount of iron-stone gravel in lower part.
3755	14–30″	brown to greyish-brown heavy clay with pockets of calcium carbonate. Light ironstone gravel throughout.
3756	30–42″	brown to greyish-brown heavy clay with ironstone gravel and pockets of calcium carbonate increasing.

13. HUNDRED OF SADDLEWORTH. Section 2803. ½ mile north-east of Saddleworth.

3757	0–4½″	brown to reddish-brown fine sandy loam.
3758	4½–14″	brown to reddish-brown fine sandy loam.
3759	14–27″	dark reddish-brown medium clay.
3760	27–39″	reddish-brown heavy clay.
3761	39–43″	brown to yellowish-brown heavy clay continuing.

14. HUNDRED OF YONGALA. Section 96. 4½ miles south of Yongala.

The first profile represents flats among slightly undulating country.

3762	0–5″	brown to reddish-brown clay loam.
3763	5–11″	reddish-brown to dark reddish-brown heavy clay.
3764	11–24″	dark reddish-brown heavy clay.
3765	24–36″	red heavy clay.
3766	36–44″	red heavy clay with calcium carbonate appearing.

The next profile was taken from the crest of the hill overlooking the site of the last sample.

3767	0–3½″	brown sand to sandy loam.
3768	3½–6″	brown to reddish-brown heavy clay.
3769	6–15″	reddish-brown and grey clay with pockets of sandy clay and decomposing sandstone showing bright red stains.

15. HUNDRED OF BELALIE. Section 208. 4½ miles south-east of Jamestown.

This profile is typical of the soils of the Belalie East valley. The surface soil runs together and sets badly on top after rain.

3770	0–3″	brown to reddish-brown loam or silty loam.
3771	3–9″	brown to reddish-brown loam or silty loam.
3772	9–22″	red to reddish-brown heavy clay.
3773	22–39″	brown to reddish-brown medium clay with calcium carbonate appearing. Becoming redder with depth.

16. HUNDRED OF BELALIE. Section 220. 5½ miles south-east of Jamestown.

A heavier soil, representing not more than 10 per cent. of the Belalie plain.

3774	0–4″	brown to reddish-brown clay loam.
3775	4–10″	dark reddish-brown clay.
3776	10–24″	dark reddish-brown clay.
3777	24–36″	dark red heavy clay continuing. A small amount of calcium carbonate appears at 30–36″.

17. HUNDRED OF BELALIE. Section 185. 5 miles north-east of Jamestown.
The two profiles collected on this section were taken from the crest of a hill and both overlie decomposed shales or slates. The second profile represents a more calcareous phase. These profiles do not belong to the red-brown earths.

3778	0–6″	greyish-brown loam or silty loam with calcium carbonate.
3779	6–13″	greyish-brown loam with calcium carbonate.
3780	13–21″	bluish-grey decomposed slate with pockets of greyish-brown loam.
3781	21–36″	bluish-grey decomposed slate continuing.

3782	0–5″	brown to greyish-brown loam with nodular calcium carbonate.
3783	5–10″	greyish-brown loam with nodular calcium carbonate and pockets of decomposed slate.
3784	10–18″	limestone marl and decomposed slate.

18. HUNDRED OF BELALIE. Section 306. ½ mile west of Belalie North railway station.

3785	0–6″	brown loam.
3786	6–14″	brown to reddish-brown clay loam.
3787	14–24″	brown to reddish-brown clay loam.
3788	24–36″	reddish-brown medium clay becoming redder and heavier with depth.

19. HUNDRED OF APPILA. Section 3. 4½ miles south-west of Yarrowie, on Gladstone-Booleroo Centre Road.

3789	0–4″	brown loam.
3790	4–12″	brown clay loam.
3791	12–30″	brown to reddish-brown light clay with considerable marl and nodular calcium carbonate.

20. HUNDRED OF APPILA. Section 508. 5 miles south of Booleroo Centre, on road between Appila and Booleroo Centre.

3792	0–6″	dark reddish-brown clay loam.
3793	6–18″	reddish-brown to dark reddish-brown loam.
3794	18–27″	reddish-brown sandy loam.
3795	27–33″	reddish-brown clay loam.
3796	33–36″	red clay with stones at 36″.

21. HUNDRED OF BOOLEROO. Section 101. 2½ miles north of Booleroo Centre.

3797	0–3″	dark brown clay.
3798	3–11″	very dark brown to chocolate heavy clay.
3799	11–18″	dark reddish-brown heavy clay with occasional stones.
3800	18–24″	reddish-brown heavy clay with marl.

22. HUNDRED OF WHYTE. Section 16. 1 mile north of Canowie Station, at the junction of the Canowie Belt and Jamestown-Canowie Roads.

3801	0–4½″	reddish-brown loam.
3802	4½–12″	reddish-brown loam.
3803	12–24″	reddish-brown clay loam.
3804	24–36″	reddish-brown clay loam with considerable amount (45%) of small waterworn slate pebbles.

23. HUNDRED OF ANNE. Section 478. Booborowie Experimental Farm.

These profiles were collected from Plot No. 5 (No Manure Plot) of the former Booborowie Experimental Farm and represent typical country on slightly rising ground above the Booborowie plain. The second profile was collected by officers of the Department of Agriculture at the time of the closing of the farm in 1930.

3805	0–6″	brown loam.
3806	6–14″	reddish-brown loam.
3807	14–21″	red heavy clay.
3808	21–38″	red heavy clay.
3809	38–44″	red heavy clay with calcium carbonate appearing at 38″ and increasing.
1854	0–4″	brown to reddish-brown loam.
1855	4–9″	brown to reddish-brown loam.
1856	9–18″	reddish-brown loam.
1857	18–27″	red medium clay.

24. HUNDRED OF ANNE. Section 498. 5 miles south of Canowie. 400 yards east of main road between Canowie and Booborowie.

This profile is typical of the heavier and very silty soils of the Booboorowie flats, which are extensively used for lucerne-growing. On these flats the water-table was originally two to three feet below the surface, but following the continued cultivation of lucerne it has now fallen to 30 or 40 feet.

3810	0–5″	greyish-brown silty clay.
3811	5–11″	greyish-brown silty clay.
3812	11–24″	dark brown heavy clay.
3813	24–30″	dark brown heavy clay with calcium carbonate appearing.
3814	30–42″	brown to dark brown heavy clay with calcium carbonate rubbie increasing.

25. HUNDRED OF WHYTE. Section 515. 1 mile south of Yarcowie.

3815	0–5″	red to reddish-brown loam.
3816	5–14″	dark red medium clay.
3817	14–19″	red heavy clay.
3818	19–25″	red heavy clay with limestone rubble increasing.

26. HUNDRED OF BELALIE. Section 715. 6½ miles south of Jamestown, along Spalding Road.

3819	0–5″	brown fine sandy loam.
3820	5–12″	brown loam.
3821	12–30″	reddish-brown heavy clay.
3822	30–36″	dark reddish-brown heavy clay.
3823	36–44″	reddish-brown clay loam to light clay with a small amount of calcareous rubble.

27. HUNDRED OF YANGYA. Section 316. 4 miles south of Caltowie, on Caltowie-Georgetown Road.

This profile represents the soil of the Manatoo plain.

3824	0–6″	dark brown clay loam.
3825	6–18″	dark brown to dark reddish-brown medium clay.
3826	18–26″	dark reddish brown medium to heavy clay.
3827	26–36″	reddish-brown heavy clay with heavy calcareous rubble continuing.

28. HUNDRED OF BUNDALEER. Section 134. 1 mile north of Abbeville railway station.

This sample is typical of the Georgetown plain and is said to represent some of the finest wheat country in South Australia.

3828	0–6″	dark reddish-brown self-mulching clay.
3829	6–18″	dark brown to dark reddish-brown heavy clay.
3830	18–28″	dark reddish brown heavy clay.
3831	28–32″	reddish-brown heavy clay with some calcium carbonate.
3832	32–44″	reddish-brown heavy clay with marl and soft calcareous rubble increasing.

29. HUNDRED OF REYNOLDS. Section 220 E. 2½ miles north-west of Spalding, on Spalding-Jamestown Road.

3833	0–3″	brown to dark brown self-mulching clay.
3834	3–9″	very dark brown medium clay—friable.

At 9″ there was a sharp change to heavy calcareous rubble.

A more typical profile was obtained from another site 200 yards away from the last sample.

3835	0–4½″	brown to red-brown clay loam.
3836	4½–18″	dark red heavy clay.
3837	18–30″	red heavy clay continuing.

A section in an adjacent water channel showed a total depth of 20-25 feet of soil.

30. HUNDRED OF GILBERT. Riverton.

Samples collected by officers of the Department of Agriculture in 1923.

36	0–8″	dark brown clay.
37	8–20″	brown heavy clay.
38	20–24″	brown to reddish-brown heavy clay with marl.

31. HUNDRED OF GILBERT. Section 294. 1 mile north-west of Tarlee.

This profile represents a heavy dark-coloured soil of the Bay of Biscay type and occurs in the depressions in undulating country. The surrounding rises are covered with typical reddish-brown soils overlying limestone at about 4 feet.

3718	0–4″	very dark brown medium clay.
3719	4–12″	very dark greyish-brown heavy clay.
3720	12–24″	dark greyish-brown heavy clay.
3721	24–36″	dark greyish-brown heavy clay with white flecks of calcium carbonate and occasional nodules of ironstone.
3722	36–54″	grey to greyish-brown heavy clay.

TABLE I

The Mechanical and Chemical Analyses of Two Red-brown Earth Profiles at the Waite Institute

Locality		HD. ADELAIDE						Section 268					
Soil No.		U 69	U 70	U 71	U 72	U 73	U 74	U 75	U 76	U 77	U 78	U 79	U 80
Depth		0–1″	1–2″	2 3″	3–4″	4–5″	5 6″	6–7″	7–8″	8–9″	9-10″	10 11″	11–12″
Horizon		A_1	A_1	A_1	A_1	A_2	A_2	A_2	A_2	A_2	A_2	A_2	A_2
Reaction	pH	6.1	6.2	6.3	6.5	6.6	6.6	6.7	6.7	6.7	6.8	6.8	6.9
		%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	—	—	—	—	—	—	—	—	—	—	—	—
Mechanical Analysis—													
Coarse Sand		4.2	4.7	5.0	5.2	5.5	5.2	5.3	5.8	4.9	5.0	4.8	4.4
Fine Sand		43.5	44.3	46.0	48.0	50.2	51.6	52.4	52.8	53.4	53.5	53.0	52.0
Silt		23.9	25.3	25.5	25.1	25.3	24.9	25.8	26.1	26.1	25.9	26.1	26.3
Clay		20.1	19.6	18.8	18.2	17.1	16.0	15.4	14.4	14.7	15.0	15.2	16.3
Loss on Acid Treatment		0.8	0.7	0.4	0.5	0.4	0.4	0.4	0.4	0.3	0.2	0.3	0.4
Moisture		2.4	1.5	1.5	1.4	1.0	0.8	0.8	0.7	0.7	0.7	0.5	0.7
Chemical Data—													
Loss on Ignition		9.1	7.0	5.6	4.6	4.0	3.6	3.1	2.8	2.7	2.5	2.5	2.5
Organic Carbon	C	3.74	2.66	1.96	1.45	1.15	0.95	0.72	0.59	—	0.43	—	0.32
Nitrogen	N	0.286	0.212	0.155	0.116	0.095	0.082	0.064	0.054	0.047	0.042	0.038	0.035
Phosphoric Acid	P_2O_5	0.074	0.065	0.053	0.048	0.045	0.042	0.042	0.040	0.039	0.038	0.036	0.037
Potash	K_2O	0.59	0.60	0.59	0.55	0.53	0.52	0.50	0.49	0.50	0.49	0.50	0.52
Chlorides	as NaCl	0.016	0.011	0.011	0.009	—	0.006	—	0.005	—	0.005	—	0.005
Reactive Manganese	Mn	330*	340*	—	420*	—	210*	—	150*	—	—	—	150*
Exchangeable Bases—		m.e.% †	m.e.% †	m.e.% †	m.e.% †		m.e.% †		m.e.% †		m.e.% †		m.e.% †
Calcium	Ca	10.28 71	9.26 72	8.16 72	6.99 72	—	5.14 70	—	3.69 67	—	3.15 66	—	3.15 62
Magnesium	Mg	2.48 17	2.05 16	1.83 16	1.54 16	—	1.29 18	—	1.01 19	—	0.97 20	—	1.26 25
Potassium	K	1.52 10	1.31 10	1.16 10	1.01 10	—	0.76 10	—	0.60 11	—	0.51 11	—	0.48 10
Sodium	Na	0.27 2	0.20 2	0.18 2	0.17 2	—	0.15 2	—	0.14 3	—	0.13 3	—	0.13 3
Total Bases		14.55 100	12.82 100	11.33 100	9.71 100		7.34 100		5.44 100		4.76 100		5.02 100
Exchangeable Hydrogen	H	7.5	6.7	5.8	4.6	—	3.2	—	2.5	—	2.1	—	1.9
Percentage Base Saturation		66	66	66	68	—	69	—	69	—	69	—	73

* = Parts per million   m.e.% = Milligram equivalents per 100 grm of soil   † = Percentage composition of the bases

TABLE I (continued)

The Mechanical and Chemical Analyses of Two Red-brown Earth Profiles at the Waite Institute

Locality	HD. ADELAIDE						Section 268					
Soil No.	U 81	U 82	U 83	U 84	U 85	U 86	U 87	U 88	U 89	U 90	U 91	U 92
Depth	12–13″	13–14″	14–15″	15–16″	16–17″	17–18″	18–19″	19–20″	20–21″	21–22″	22–23″	23–24″
Horizon	A_2	A_2	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1
Reaction pH	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.2	7.1	7.1
	%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	—	—	—	—	—	—	—	—	—	—	—	—
Mechanical Analysis—												
Coarse Sand	4.9	4.3	4.5	4.4	4.2	3.7	4.0	4.8	5.0	4.9	5.4	5.7
Fine Sand	50.5	49.5	47.8	45.5	43.8	41.4	39.4	38.3	38 4	38.8	39.3	40.0
Silt	25.9	25.6	24.8	23.4	23.1	22.7	21.5	20.2	19.7	20.1	20.0	18.9
Clay	17.5	19.4	21.7	24.6	27.5	30.7	32.8	34.8	35.4	35.0	33.5	33.0
Loss on Acid Treatment	0.3	0.5	0.4	0.3	0.4	0.3	0.4	0.7	0.5	0.6	0.7	0.6
Moisture	0.7	0.7	0.9	1.2	1.4	1.4	1.8	1.4	1.8	2.4	2.4	2.2
Chemical Data—												
Loss on Ignition	2.7	2.8	3.0	3.2	3.5	3.8	4.2	4.2	4.2	4.4	4.3	4.2
Organic Carbon C	—	0.28	—	0.25	—	0.27	—	0.26	—	0.23	—	0.21
Nitrogen N	0.033	0.034	0.033	0.033	0.034	0.036	0.038	0.036	0.034	0.034	0.032	0.032
Phosphoric Acid P_2O_5	0.034	0.035	0.038	0.039	0.043	0.041	0.045	0.046	0.046	0.046	0.045	0.044
Potash K_2O	0.54	0.56	0.60	0.64	0.73	0.67	0.73	0.75	0.75	0.72	0.71	0.70
Chlorides as NaCl	—	0.005	—	0.005	—	0.005	—	0.005	—	0.005	—	0.005
Exchangeable Bases—		m.e.% †		m.e.% †		m.e.% †		m.e.% †		m.e.% †		m.e.% †
Calcium Ca	—	3.38 59	—	3.84 55	—	4.78 52	—	5.36 50	—	5.70 50	—	5.10 48
Magnesium Mg	—	1.67 29	—	2.33 34	—	3.48 38	—	4.42 41	—	4.70 41	—	4.63 43
Potassium K	—	0.52 9	—	0.61 9	—	0.71 8	—	0.76 7	—	0.74 6	—	0.68 6
Sodium Na	—	0.16 3	—	0.16 2	—	0.20 2	—	0.24 2	—	0.29 3	—	0.29 3
Total Bases	—	5.73 100	—	6.94 100	—	9.17 100	—	10.78 100	—	11.43 100	—	10.70 100
Exchangeable Hydrogen H	—	2.0	—	2.4	—	3.1	—	3.6	—	3.5	—	3.5
Percentage Base Saturation	—	74	—	74	—	75	—	75	—	76	—	76

m.e.% = Milligram equivalents per 100 grm. of soil † = Percentage composition of the bases

TABLE I (continued)

The Mechanical and Chemical Analyses of Two Red-brown Earth Profiles at the Waite Institute

Locality	HD. ADELAIDE								Section 268				
Soil No.	U 93	U 94	U 95	U 97	U 98	U 99	U 100	U 101	U 102	U 103	U 104	U 105	U 106
Depth	24–25″	25–26″	26–29″	29–30″	30–31″	31–32″	32–33″	33–34″	34–35″	35–36″	36–37″	37–38″	38–39″
Horizon	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1	B_1
Reaction .... pH	7.1	7.1	7.1	7.1	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
	%	%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	—	—	—	—	—	—	—	—	-	—	—	—	—
Mechanical Analysis—													
Coarse Sand	5.4	6.4	5.2	1.8	4.1	2.1	2.7	2.0	2.2	2.1	1.9	2.2	2.3
Fine Sand	40.3	38.5	36.3	17.3	29.5	17.5	22.4	18.8	17.4	17.7	16.9	17.8	17.1
Silt	18.9	18.6	16.8	9.8	15.1	9.5	12.2	10.5	9.5	9.8	9.3	9.8	8.8
Clay	33.2	34.9	39.2	67.0	49.2	66.2	58.0	64.9	67.0	66.9	67.9	65.9	67.0
Loss on Acid Treatment	0.5	0.6	0.5	1.0	0.7	0.8	1.4	1.3	1.4	1.4	1.4	1.4	1.3
Moisture	2.5	2.6	2.9	5.6	3.7	4.8	4.6	4.6	4.9	4.4	5.0	4.8	5.5
Chemical Data –													
Loss on Ignition	4.2	4.4	4.8	7.2	5.6	6.5	7.4	7.2	7.2	7.2	7.3	7.0	7.1
Organic Carbon C	—	0.22	0.21	0.23	—	0.25	—	—	—	0.24	—	—	—
Nitrogen .... N	0.032	0.032	0.022	0.038	0.024	0.039	0.040	0.040	0.038	0.037	0.037	0.038	0.039
Phosphoric Acid P_2O_5	0.045	0.045	0.040	0.032	0.035	0.033	0.032	0.031	0.031	0.031	0.031	0.032	0.031
Potash .... K_2O	0.68	0.70	0.77	1.16	0.85	1.04	1.07	1.10	1.16	1.14	1.16	1.17	1.08
Chlorides as NaCl	—	0.005	0.008	0.011	—	0.009	—	0.009	—	0.011	—	0.011	—
Exchangeable Bases—		m.e.% †	m.e.% †			m.e.% †				m.e.% †			
Calcium .... Ca	—	5.65 48	6.88 49	—	—	11.64 50	—	—	—	14.07 51	—	—	—
Magnesium .... Mg	—	5.01 43	5.76 42	—	—	9.37 41	—	—	—	10.91 40	—	—	—
Potassium .... K	—	0.70 6	0.74 5	—	—	1.01 4	—	—	—	1.19 4	—	—	—
Sodium .... Na	—	0.39 3	0.55 4	—	—	1.04 5	—	—	—	1.36 5	—	—	—
Total Bases	—	11.75 100	13.93 100			23.06 100				27.53 100			
Exchangeable Hydrogen H	—	3.6	3.8	—	—	5.3				5.7			
Percentage Base Saturation	—	77	79	—	—	81	—	—	—	83			

m.e.% = Milligram equivalents per 100 grm. of soil † = Percentage composition of the bases

TABLE I (continued)

The Mechanical and Chemical Analyses of Two Red-brown Earth Profiles at the Waite Institute

Locality		HD. ADELAIDE	Section 268				HD. ADELAIDE	Section 250					
Soil No.		U 107	U 108	U 109	U 110	U 111	U 151	U 152	U 153	U 154	U 155	U 156	U 157
Depth		39–40″	40–41″	41–42″	42–43″	43–46″	0–4″	4–9″	9–18″	18–27″	27–36″	36–45″	45–54″
Horizon		B_1	B_1	B_1	B_1	B_1	A_1	A_2	B_1	B_1	B_1	B_2C	B_2C
Reaction	pH	7.3	7.3	7.4	7.5	7.5	6.0	5.8	6.2	6.7	7.2	8.4	8.6
		%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	—	—	—	—	—	0.02	tr.	0.01	nil	0.13	4.80	3.96
Mechanical Analysis—													
Coarse Sand		2.0	2.5	2.4	3.0	3.8	2.1	1.9	1.2	0.7	0.6	0.8	1.3
Fine Sand		16.1	15.6	16.1	17.2	18.7	43.7	40.8	26.3	18.6	19.2	24.5	25.3
Silt		8.1	9.0	8.8	9.3	9.0	24.8	33.8	22.8	18.8	19.3	28.4	29.7
Clay		68.4	67.9	67.5	64.3	62.9	18.0	21.8	47.4	59.9	59.2	40.7	37.2
Loss on Acid Treatment		1.4	1.5	1.4	1.5	1.0	1.0	0.7	1.1	1.4	1.6	6.3	5.2
Moisture		6.0	6.3	5.9	5.8	5.7	0.4	0.6	1.2	2.0	1.7	1.2	1.1
Chemical Data—													
Loss on Ignition		7.3	7.5	7.3	7.1	6.4	4.4	4.1	6.2	7.3	7.2	7.3	6.7
Organic Carbon	C	0.26	—	0.29	—	0.23	1.32	1.07	0.76	0.67	0.66	0.41	0.30
Nitrogen	N	0.039	0.042	0.042	0.039	0.035	0.103	0.091	0.084	0.077	0.073	0.046	0.035
Phosphoric Acid	P_2O_5	0.031	0.032	0.032	0.031	0.032	0.047	0.046	0.051	0.050	0.045	0.032	0.028
Potash	K_2O	1.10	1.14	1.09	1.13	1.06	0.52	0.59	0.93	1.11	1.08	0.99	0.93
Chlorides	as NaCl	0.012	—	0.012	—	0.012	0.013	0.008	0.008	0.010	0.012	0.015	0.016
Reactive Manganese	Mn	—	—	—	—	—	430*	390*	180*	110*	120*	180*	230*
Exchangeable Bases—		m.e.% †		m.e.% †		m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †
Calcium	Ca	16.17 52	—	17.28 53	—	17.22 54	4.49 64	4.87 65	8.88 59	13.16 57	15.07 60	17.74 71	15.87 68
Magnesium	Mg	11.89 39	—	12.46 38	—	11.76 37	1.36 19	1.69 23	4.81 32	7.77 34	8.04 32	5.56 22	5.94 25
Potassium	K	1.27 4	—	1.29 4	—	1.25 4	0.83 12	0.65 9	0.97 6	1.31 6	1.36 5	1.04 4	0.97 4
Sodium	Na	1.58 5	—	1.70 5	—	1.67 5	0.32 5	0.23 3	0.46 3	0.66 3	0.66 3	0.64 3	0.80 3
Total Bases		30.91 100	—	32.73 100	—	31.90 100	7.00 100	7.44 100	15.12 100	22.90 100	25.13 100	24.98 100	23.58 100
Exchangeable Hydrogen	H	5.1	—	4.7	—	3.9	5.2	5.2	6.4	6.5	5.4	0.9	0.5
Percentage Base Saturation		86		87		89	57	59	70	78	82	97	98
Composition of Clay Fraction—													
$\frac{SiO_2}{Al_2O_3}$							3.43	3.27	2.86	2.85	2.86	3.16	3.22
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$							2.53	2.41	2.13	2.12	2.13	2.32	2.34

* = Parts per million m.e.% = Milligram equivalents per 100 grm of soil † = Percentage composition of the bases

TABLE II

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality	HD. YATALA				Section 2186		HD. ALMA			Section 211	
Soil No.	3694	3695	3696	3697	3698	3699	3734	3735	3736	3737	3738
Depth	0–4″	4–9″	9 13″	13–21″	22–30″	30–41″	0 4″	4–9″	9–18″	18–21″	21–36″
Horizon	A_1	A_2	B_1	B_2	B_2C	B_2C	A_1	A_2	B_1	B_2	B_2C
Reaction pH	7.4	8.2	9.1	9.5	9.6	9.5	6.4	7.2	7.6	8.2	8.4
	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	0.01	0.01	0.04	0.89	19.3	24.6	tr.	tr.	0.01	0.52	4.04
Mechanical Analysis—											
Coarse Sand	14.1	20.5	8.3	3.3	2.6	2.5	14.0	12.1	3.4	3.8	5.9
Fine Sand	41.2	42.1	24.1	13.1	10.3	12.0	55.2	54.3	16.3	19.2	25.5
Silt	21.5	18.0	10.3	8.5	8.0	8.4	13.4	16.3	6.7	10.0	12.2
Clay	19.7	17.7	50.9	62.9	51.9	44.9	13.9	14.9	61.4	55.6	43.7
Loss on Acid Treatment	0.8	0.4	1.6	3.2	21.4	26.1	0.7	0.5	1.7	2.7	6.1
Moisture	1.7	1.2	5.4	9.7	7.5	7.1	1.5	1.4	10.3	10.1	8.1
Chemical Data—											
Loss on Ignition	4.4	2.7	5.0	6.1	13.1	14.8	3.5	2.6	6.9	6.0	6.1
Organic Carbon C	1.25	0.41	0.26	0.22	0.15	0.12	0.79	0.35	0.77	0.47	0.22
Nitrogen N	0.113	0.047	0.046	0.029	0.023	0.018	0.084	0.044	0.092	0.058	0.031
Phosphoric Acid P_2O_5	0.060	0.037	0.038	0.039	0.023	0.032	0.035	0.030	0.046	—	0.032
Potash K_2O	0.67	0.62	1.64	2.13	1.81	1.48	0.53	0.51	1.48	—	1.25
Chlorides as NaCl	0.020	0.026	0.061	0.112	0.166	0.190	0.012	0.008	0.143	0.333	0.353
Reactive Manganese Mn	200*	—	—	—	—	—	240*	—	—	—	—
Exchangeable Bases—	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †		m.e.% †
Calcium Ca	8.11 68	3.17 50	3.31 15	3.32 12	2.09 9	2.22 11	3.60 51	1.97 42	6.05 21	—	5.17 19
Magnesium Mg	2.57 21	2.11 33	9.05 40	7.91 30	6.76 29	5.93 30	1.53 22	1.39 29	14.10 48	—	14.07 53
Potassium K	0.84 7	0.61 10	2.53 11	3.58 13	2.82 12	2.09 10	1.51 22	0.92 19	3.02 10	—	2.50 9
Sodium Na	0.49 4	0.48 7	7.72 34	12.19 45	11.51 50	9.87 49	0.32 5	0.49 10	6.14 21	—	5.19 19
Total Bases	12.01 100	6.37 100	22.61 100	27.00 100	23.18 100	20.11 100	6.96 100	4.77 100	29.31 100	—	26.93 100
Exchangeable Hydrogen H	2.3	1.4	nil	nil	nil	nil	2.7	2.2	2.2	nil	nil
Percentage Base Saturation	84	82	100	100	100	100	72	68	93	100	100
Composition of Clay Fraction—											
$\frac{SiO_2}{Al_2O_3}$	3.40	3.41	3.22	3.30	3.46	3.49	3.22	3.41	3.09	3.37	3.54
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	2.66	2.72	2.56	2.59	2.69	2.70	2.62	2.69	2.50	2.72	2.85

* = Parts per million   m.e.% = Milligram equivalents per 100 grm of soil   † = Percentage composition of the bases

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality		HD. GILBERT				Section 12				HD. GILBERT		Section 504	
Soil No.		3704	3701	3702	3703	3705	3706	3707	3708	3714	3715	3716	3717
Depth		0–1″	0–4″	4–12″	12–18″	0–6″	6–18″	18–36″	36–42″	0–6″	6–12″	12–25″	25–42″
Horizon		—	AB	B	C	A	B_1	B_2	B_2C	A	B_1	B_2	B_2C
Reaction	pH	7.8	8.4	8.7	8.6	7.4	8.4	9.0	8.8	9.0	9.1	8.8	8.9
		%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	0.03	0.49	3.07	0.31	0.03	0.88	3.47	2.98	0.57	0.08	2.42	28.3
Mechanical Analysis—													
Coarse Sand		2.5	1.5	1.0	1.0	1.1	0.7	0.8	0.8	1.1	0.5	0.4	0.3
Fine Sand		43.0	29.3	22.1	23.6	29.3	18.2	20.1	19.4	30.3	15.3	11.5	9.9
Silt		16.7	16.6	21.3	28.7	26.7	28.6	29.2	27.3	19.7	10.8	11.5	9.5
Clay		32.6	43.9	43.0	38.9	36.2	43.6	40.0	43.2	40.2	60.5	60.6	42.8
Loss on Acid Treatment		0.7	2.0	5.1	2.4	1.1	2.5	4.6	5.1	3.3	2.5	4.8	20.6
Moisture		3.9	6.4	8.0	8.1	5.3	7.2	6.3	6.8	5.6	11.4	13.0	8.8
Chemical Data—													
Loss on Ignition		4.8	5.7	6.3	4.8	5.7	6.2	6.3	6.2	6.5	6.3	7.0	16.5
Organic Carbon	C	0.70	0.58	0.31	0.15	1 05	0.65	0.29	0.41	0.96	0.84	0.55	0.25
Nitrogen	N	0.083	0.080	0.054	0.038	0.109	0.090	0.053	0.063	0.093	0.090	0.065	0.026
Phosphoric Acid	P_2O_5	0.053	0.045	0.032	0.030	0.041	0.032	0.025	—	0.043	0.031	—	—
Potash	K_2O	0.73	0.91	0.99	1.07	0.87	0.97	0.88	—	1.13	1.57	—	—
Chlorides	as NaCl	0.028	0.073	0.282	0.345	0.012	0.013	0.018	0.018	0.035	0.069	0.125	0.133
Reactive Manganese	Mn	210*	240*	—	—	420*	—	—	—	340*	—	—	—
Exchangeable Bases—		m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †
Calcium	Ca	5.65 37	6.76 30	8.39 28	5.77 19	14.65 68	20.77 71	14.79 52	17.92 62	13.19 51	11.35 29	7.86 20	5.44 18
Magnesium	Mg	6.06 40	9.01 39	10.39 34	12.05 40	5.46 25	6.90 24	11.27 39	9.17 31	7.10 27	15.87 41	20.32 50	16.42 56
Potassium	K	0.90 6	1.06 5	1.12 4	1.09 4	0.99 5	0.67 2	0.57 2	0.64 2	1.78 7	2.66 7	3.22 8	2.51 8
Sodium	Na	2.49 17	5.95 26	10.34 34	11.39 37	0.37 2	0.74 3	2.03 7	1.41 5	3.76 15	8.78 23	9.00 22	5.17 18
Total Bases		15.10 100	22.78 100	30.24 100	30.30 100	21.47 100	29.08 100	28.66 100	29.14 100	25.83 100	38.66 100	40.40 100	29.54 100
Exchangeable Hydrogen	H	2.6	1.2	nil	nil	2.9	0.8	nil	0.2	0.2	nil	nil	nil
Percentage Base Saturation		85	95	100	100	88	97	100	100	99	100	100	100
Composition of Clay Fraction—													
$\frac{SiO_2}{Al_2O_3}$		2.89	3.11	3.52	3.79	3.05	3.15	3.31	3.19	3.61	3.58	3.72	3.76
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$		2.24	2.40	2.71	2.90	2.33	2.38	2.48	2.41	2.86	2.85	2.95	2.98

* = Parts per million   m.e.% = Milligram equivalents per 100 grm of soil   † = Percentage composition of the bases

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality	HD. GILBERT						Section 279	HD. BELVIDERE			Section 2996
Soil No.	3723	3724	3725	3726	3727	3728	3729	3730	3731	3733	3732
Depth	0–6″	6–15″	15–22″	22–30″	30–42″	42–54″	54–69″	0–6″	6–16″	16–24″	24–36″
Horizon	A	B_1	B_2	B_2C	C	C	C	A_1	A_2	B_1	B_2
Reaction pH	7.9	8.4	9.0	9.3	9.3	9.3	9.4	7.0	7.1	7.8	8.4
	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	0.02	0.02	1.18	12.6	6.79	10.0	15.2	0.01	0.01	0.01	0.52
Mechanical Analysis—											
Coarse Sand	2.5	0.7	0.8	0.9	1.2	1.6	3.2	5.0	4.2	0.9	2.2
Fine Sand	42.4	14.3	15.5	16.7	19.9	20.9	26.6	68.1	65.0	49.8	19.1
Silt	29.5	13.5	15.8	16.9	23.1	22.9	21.3	13.1	12.7	10.2	11.1
Clay	21.5	61.3	57.2	44.6	40.9	37.9	28.5	11.2	16.3	34.6	54.8
Loss on Acid Treatment	0.6	1.7	3.2	14.5	7.9	10.8	16.5	0.4	0.5	1.2	2.5
Moisture	2.7	9.5	8.8	7.3	7.2	6.3	4.6	0.8	1.2	4.6	10.2
Chemical Data—											
Loss on Ignition	4.6	7.2	6.6	10.1	7.5	8.5	10.2	2.7	2.5	4.2	5.6
Organic Carbon C	0.83	0.70	0.37	0.21	0.18	0.18	0.10	0.74	0.34	0.26	0.18
Nitrogen N	0.092	0.091	0.061	0.037	0.034	0.031	0.025	0.063	0.039	0.036	0.039
Phosphoric Acid P_2O_5	0.045	0.048	0.040	0.029	0.027	0.027	0.027	0.029	0.026	—	—
Potash K_2O	0.79	1.51	1.62	1.41	1.38	1.23	1.03	0.56	0.63	—	—
Chlorides as NaCl	0.016	0.028	0.033	0.033	0.045	0.046	0.045	0.005	0.007	0.020	0.183
Reactive Manganese Mn	440*	—	—	—	—	—	—	290*	—	—	—
Exchangeable Bases—	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †	m.e.%	m.e.% †	m.e.%	m.e.%	m.e.%	m.e.%
Calcium Ca	6.78 55	8.93 32	7.06 22	—	4.60 17	—	4.25 22	—	—	—	—
Magnesium Mg	3.50 29	12.78 45	15.75 49	—	12.84 47	—	9.15 46	—	—	—	—
Potassium K	1.23 10	2.38 8	2.80 9	—	2.40 9	—	1.48 7	—	—	—	—
Sodium Na	0.78 6	4.40 15	6.36 20	—	7.35 27	—	5.01 25	—	—	—	—
Total Bases	12.29 100	28.49 100	31.97 100	—	27.19 100	—	19.89 100	—	—	—	—
Exchangeable Hydrogen H	1.6	2.5	nil	nil	nil	nil	nil	1.6	1.6	1.4	nil
Percentage Base Saturation	89	92	100	100	100	100	100	—	—	—	—
Composition of Clay Fraction—											
$\frac{SiO_2}{Al_2O_3}$	3.37	3.11	3.35	3.60	3.57	3.50	3.59	—	—	—	—
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	2.61	2.46	2.66	2.83	2.78	2.71	2.78	—	—	—	—

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality	HD. BLYTH		Section 192/193		HD. CLARE			Section 515		HD. BOOLEROO			Section 101
Soil No.	3739	3740	3741	3742	3743	3744	3745	3746	3747	3797	3798	3799	3800
Depth	0–7″	7–14″	14–30″	30–42″	0–4½″	4½–10″	10–20″	20–24″	24–33″	0–3″	3–11″	11–18″	18–24″
Horizon	A	B	BC	BC	A_1	A_2	B_1	B_2	B_2C	A	AB	B	BC
Reaction .... pH	8.4	8.7	9.2	9.6	6.4	7.0	7.7	8.6	8.7	8.5	8.4	8.6	8.8
	%	%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	2.23	15.7	18.4	29.8	0.01	tr.	0.02	5.06	16.7	2.13	0.20	1.62	35.5
Mechanical Analysis—													
Coarse Sand	8.9	5.2	4.2	3.4	3.6	4.1	0.9	0.7	0.5	12.9	12.7	12.5	8.8
Fine Sand	50.9	34.7	33.1	29.6	38.1	40.0	12.4	9.1	9.3	23.3	19.1	17.1	11.2
Silt	13.2	13.3	13.2	12.2	32.7	32.9	15.2	17.5	22.4	16.6	12.1	7.9	4.9
Clay	18.8	22.1	21.4	19.2	19.9	20.2	61.6	58.3	43.0	36.2	47.0	51.3	32.4
Loss on Acid Treatment	4.5	19.0	22.1	32.1	0.5	0.4	1.3	6.9	18.9	4.6	2.7	3.9	38.3
Moisture	3.4	4.5	4.5	3.9	2.8	1.5	8.9	8.3	6.3	6.2	7.9	8.8	5.1
Chemical Data—													
Loss on Ignition	6.1	11.6	12.5	16.5	5.4	3.4	7.6	9.2	13.0	9.3	7.5	7.1	20.1
Organic Carbon C	1.43	0.79	0.45	—	1.53	0.54	0.79	0.59	0.35	2.30	1.48	0.91	0.54
Nitrogen .... N	0.131	0.072	0.042	0.029	0.156	0.081	0.110	0.096	0.075	0.187	0.122	0.085	0.050
Phosphoric Acid P_2O_5	0.073	0.087	—	—	0.049	0.038	0.048	—	0.035	0.055	0.046	0.046	—
Potash .... K_2O	0.81	0.86	—	—	0.64	0.68	1.22	—	0.98	1.02	1.19	1.26	—
Chlorides as NaCl	0.013	0.013	0.015	0.038	0.008	0.005	0.020	0.048	0.109	0.021	0.020	0.018	0.010
Reactive Manganese Mn	190*	—	—	—	350*	—	—	—	—	170*	—	—	—
Exchangeable Bases—	m.e.%	m.e.%			m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †
Calcium .... Ca	—	—	—	—	4.76 64	2.64 54	10.80 45	—	8.79 42	30.94 83	28.66 77	—	14.24 68
Magnesium .... Mg	—	—	—	—	1.49 20	1.42 29	9.31 39	—	8.34 39	3.75 10	5.43 15	—	4.94 23
Potassium .... K	—	—	—	—	0.95 13	0.54 11	1.52 6	—	0.98 5	2.26 6	2.68 7	—	1.53 7
Sodium .... Na	—	—	—	—	0.22 3	0.28 6	2.36 10	—	3.01 14	0.40 1	0.49 1	—	0.45 2
Total Bases	—	—	—	—	7.42 100	4.88 100	23.99 100	—	21.12 100	37.35 100	37.26 100	—	21.16 100
Exchangeable Hydrogen H	0.3	0.1	nil	nil	4.2	2.4	3.9	0.5	nil	0.6	0.6	0.5	nil
Percentage Base Saturation	—	—	—	—	64	67	86	—	100	98	98	—	100
Composition of Clay Fraction: $\frac{SiO_2}{Al_2O_3}$	—	—	—	—	3.09	3.03	2.97	3.09	3.14	—	—	—	—
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	—	—	—	—	2.61	2.58	2.45	2.56	2.63	—	—	—	—

* = Parts per million m.e.% = Milligram equivalents per 100 grm of soil † = Percentage composition of the bases

Table II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality	HD. HANSON Section 432					HD. YONGALA Section 96					HD. YONGALA Section 96		
Soil No.	3748	3749	3750	3751	3752	3762	3763	3764	3765	3766	3767	3768	3769
Depth	0–4½″	4½–9″	9–16″	16–32″	32–40″	0–5″	5–11″	11–24″	24–36″	36–44″	0–3½″	3½–6″	6–15″
Horizon	A	B_1	B_1	B_2	C	A	AB_1	B_1	B_1	B_2C	A	B	BC
Reaction .... pH	6.8	7.3	7.6	8.8	9.0	6.8	7.3	7.8	8.5	8.8	6.9	8.2	9.0
	%	%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	0.01	0.02	0.01	33.8	26.3	tr.	0.01	0.01	0.76	2.43	0.01	0.07	15.8
Mechanical Analysis—													
Coarse Sand	8.5	4.3	2.1	1.2	4.1	11.2	6.9	3.7	4.7	5.5	27.8	7.8	8.6
Fine Sand	44.3	35.8	15.8	10.0	17.2	33.2	23.7	13.4	16.1	19.0	52.1	20.9	21.2
Silt	21.5	22.9	10.5	10.1	23.2	20.9	15.3	9.7	10.6	13.0	7.3	7.4	7.6
Clay	21.4	32.4	61.1	35.9	24.6	29.1	46.2	61.6	56.0	49.8	10.4	57.1	39.1
Loss on Acid Treatment	0.7	0.7	1.1	35.7	27.8	1.2	1.5	1.9	2.7	4.3	0.5	1.5	17.4
Moisture	2.3	3.0	8.1	5.5	3.0	4.1	7.0	11.4	11.3	10.1	0.9	5.5	5.4
Chemical Data—													
Loss on Ignition	5.2	5.2	7.6	20.5	17.1	5.0	5.6	6.7	6.4	6.5	3.5	8.8	13.8
Organic Carbon C	1.17	0.80	0.66	0.67	0.20	0.85	0.46	0.40	0.25	0.13	0.71	0.83	0.54
Nitrogen .... N	0.019	0.086	0.083	0.063	0.027	0.088	0.063	0.061	0.048	0.034	0.068	0.091	0.053
Phosphoric Acid P_2O_5	0.052	0.053	0.054	0.039	—	0.068	0.062	0.068	—	0.058	—	—	—
Potash .... K_2O	0.62	0.77	1.28	0.85	—	0.85	1.08	1.36	—	1.20	—	—	—
Chlorides as NaCl	0.012	0.010	0.015	0.018	0.012	0.008	0.008	0.010	0.012	0.010	0.008	0.036	0.046
Reactive Manganese Mn	300*	—	—	—	—	420*	—	—	—	—	40*	—	—
Exchangeable Bases—	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †			
Calcium .... Ca	6.44 68	7.60 72	15.44 73	13.34 72	—	6.81 54	8.89 51	12.21 50	—	10.77 47	—	—	—
Magnesium .... Mg	1.68 18	1.81 17	3.57 17	3.29 18	—	4.27 33	6.54 38	9.74 40	—	9.56 42	—	—	—
Potassium .... K	1.01 11	0.90 8	1.33 6	0.71 4	—	1.45 11	1.63 9	1.99 8	—	1.81 8	—	—	—
Sodium .... Na	0.24 3	0.29 3	0.94 4	1.11 6	—	0.21 2	0.33 2	0.60 2	—	0.78 3	—	—	—
Total Bases	9.37 100	10.60 100	21.28 100	18.45 100		12.74 100	17.39 100	24.54 100	—	22.92 100	—	—	—
Exchangeable Hydrogen H	3.0	2.7	3.6	0.1	nil	3.4	3.0	2.7	0.5	nil	—	—	—
Percentage Base Saturation	76	80	85	100	100	79	85	90	—	100	—	—	—
Composition of Clay Fraction:													
$\frac{SiO_2}{Al_2O_3}$	3.01	2.95	2.88	2.99	2.94	—	—	—	—	—	—	—	—
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	2.40	2.34	2.36	2.45	2.39	—	—	—	—	—	—	—	—

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality	HD. STANLEY Section 290				HD. SADDLEWORTH Section 2803					HD. WHYTE Section 16			
Soil No.	3753	3754	3755	3756	3757	3758	3759	3760	3761	3801	3802	3803	3804
Depth	0–4"	4–14"	14–30"	30–42"	0–4½"	4½–14"	14–27"	27–39"	39–43"	0–4½"	4½–12"	12–24"	24–36"
Horizon	A	B	B	BC	A_1	A_2	B_1	B_1	B_2C	A	B	B	C
Reaction .... pH	8.2	8.6	8.9	8.7	6.2	7.1	7.3	7.6	8.6	6.9	6.8	7.1	7.2
	%	%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	1.30	3.59	6.06	6.47	0.01	0.01	nil	0.01	2.05	nil	nil	nil	nil
Mechanical Analysis—													
Coarse Sand	2.3	2.3	2.3	2.1	7.3	4.6	3.3	0.6	3.5	9.6	11.6	14.0	27.7
Fine Sand	22.2	18.8	18.0	17.7	58.1	47.3	31.0	35.5	25.4	43.1	39.4	37.7	23.5
Silt	10.0	8.5	9.0	9.7	17.5	23.7	16.8	8.5	13.1	26.4	25.9	21.8	18.6
Clay	51.3	55.0	53.9	53.6	13.6	21.4	41.7	47.0	45.2	16.0	20.4	23.6	26.0
Loss on Acid Treatment	4.3	7.2	8.7	9.3	0.7	0.7	1.3	1.4	4.0	0.8	0.8	0.9	0.9
Moisture	8.5	8.2	8.9	9.0	1.7	2.5	6.7	7.0	9.2	2.3	2.2	2.5	3.3
Chemical Data—													
Loss on Ignition	9.2	9.1	8.8	8.7	3.1	2.9	4.2	5.3	5.1	4.3	3.7	3.7	4.2
Organic Carbon C	2.10	0.93	0.55	0.42	0.78	0.37	0.30	0.43	0.10	0.99	0.54	0.36	0.26
Nitrogen .... N	0.203	0.099	0.060	0.048	0.083	0.056	0.053	0.059	0.030	0.122	0.085	0.066	0.064
Phosphoric Acid P_2O_5	0.057	0.038	—	—	0.037	0.037	0.028	—	—	0.076	0.070	0.077	—
Potash .... K_2O	1.29	1.20	—	—	0.54	0.72	1.09	—	—	0.85	0.88	0.90	—
Chlorides as NaCl	0.028	0.020	0.028	0.084	0.010	0.006	0.051	0.015	0.176	0.008	0.006	0.006	0.005
Reactive Manganese Mn	160*	—	—	—	390*	—	—	—	—	460*	—	—	—
Exchangeable Bases—	m.e.%	m.e.%	m.e.%	m.e.%	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †
Calcium .... Ca	—	—	—	—	2.24 49	1.95 35	3.52 21	—	5.48 21	5.28 65	4.12 59	4.60 53	5.17 49
Magnesium .... Mg	—	—	—	—	1.44 31	2.63 47	9.62 56	—	14.84 56	1.63 20	2.00 28	3.05 35	4.17 40
Potassium .... K	—	—	—	—	0.79 17	0.67 12	1.37 8	—	1.97 7	1.07 13	0.78 11	0.84 10	0.90 9
Sodium .... Na	—	—	—	—	0.14 3	0.37 6	2.54 15	—	4.32 16	0.14 2	0.14 2	0.21 2	0.25 2
Total Bases	—	—	—	—	4.61 100	5.62 100	17.05 100	—	26.61 100	8.12 100	7.04 100	8.70 100	10.49 100
Exchangeable Hydrogen H	0.9	0.4	0.2	0.1	3.2	3.0	2.7	3.4	nil	2.9	3.2	2.7	2.8
Percentage Base Saturation	—	—	—	—	59	65	86	—	100	74	69	76	79
Composition of Clay Fraction:													
$\frac{SiO_2}{Al_2O_3}$	—	—	—	—	3.47	3.39	3.32	—	3.67	3.08	2.96	2.86	2.91
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	—	—	—	—	2.65	2.55	2.60	—	2.90	2.19	2.11	2.06	2.12

* = Parts per million   m.e.% = Milligram equivalents per 100 grm of soil   † = Percentage composition of the bases

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality		HD. BELALIE		Section 208		HD. BELALIE		Section 220		HD. BELALIE		Section 306	
Soil No.		3770	3771	3772	3773	3774	3775	3776	3777	3785	3786	3787	3788
Depth		0–3"	3–9"	9–22"	22–39"	0 4"	4–10"	10–24"	24–36"	0 6"	6–14"	14–24"	24–36"
Horizon		A_1	A_2	B_1	B_2	A_1	A_2B	A_2B	B	A_1	A_2	A_2B	B
Reaction	pH	6.3	6.6	7.8	8.7	6.8	7.4	8.1	8.5	5.8	6.5	7.0	7.9
		%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	0.01	nil	0.01	0.46	0.01	0.01	0.01	0.28	0.01	0.01	0.01	0.01
Mechanical Analysis—													
Coarse Sand		1.0	0.9	0.3	3.7	8.0	7.8	7.5	5.0	6.0	6.4	11.9	6.1
Fine Sand		41.4	40.2	24.0	20.6	21.0	29.4	28.9	18.4	31.8	25.9	33.7	29.7
Silt		38.6	37.3	21.0	29.1	23.0	18.8	19.0	13.8	38.6	35.3	25.5	15.8
Clay		16.5	18.8	47.7	40.3	31.6	37.8	38.9	54.7	19.2	28.9	24.3	41.2
Loss on Acid Treatment		0.6	0.5	1.4	1.7	1.5	1.5	1.3	2.0	0.5	0.5	0.6	1.1
Moisture		1.3	1.5	7.6	5.7	5.1	5.3	5.8	8.6	2.2	2.9	3.5	6.9
Chemical Data—													
Loss on Ignition		3.5	2.1	5.6	4.8	5.6	5.2	4.8	6.0	5.2	4.7	4.1	5.3
Organic Carbon	C	0.65	0.34	0.48	0.23	1.08	0.61	0.43	0.40	1.09	0.52	0.26	0.33
Nitrogen	N	0.088	0.071	0.078	0.054	0.114	0.075	0.061	0.060	0.152	0.109	0.072	0.063
Phosphoric Acid	P_2O_5	0.064	0.051	0.074	—	0.069	0.061	0.053	—	0.077	0.088	0.071	—
Potash	K_2O	1.01	1.09	1.34	—	1.21	1.21	1.20	—	1.05	1.24	1.07	—
Chlorides	as NaCl	0.013	0.012	0.035	0.063	0.015	0.015	0.015	0.016	0.010	0.016	0.028	0.059
Reactive Manganese	Mn	550*	—	—	—	310*	—	—	—	750*	—	—	—
Exchangeable Bases—		m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †
Calcium	Ca	3.25 60	2.59 49	6.93 33	5.09 28	13.44 68	14.56 70	13.00 64	14.13 52	4.53 62	4.43 53	3.96 41	7.88 39
Magnesium	Mg	1.14 21	1.63 31	9.65 47	8.90 49	4.29 21	4.81 23	5.65 28	9.65 35	1.46 20	3.11 37	4.13 43	8.51 43
Potassium	K	0.86 16	0.60 11	1.35 7	1.27 7	1.95 10	1.32 6	1.09 5	1.83 7	0.99 14	0.51 6	0.50 5	1.04 5
Sodium	Na	0.18 3	0.46 9	2.70 13	2.98 16	0.19 1	0.20 1	0.54 3	1.58 6	0.26 4	0.36 4	1.02 11	2.63 13
Total Bases		5.43 100	5.28 100	20.63 100	18.24 100	19.87 100	20.89 100	20.28 100	27.19 100	7.24 100	8.41 100	9.61 100	20.06 100
Exchangeable Hydrogen	H	3.0	2.6	2.4	0.1	3.2	2.0	1.3	1.1	5.0	3.9	3.0	2.0
Percentage Base Saturation		64	67	90	100	86	91	94	96	59	68	76	91
Composition of Clay Fraction—													
$\frac{SiO_2}{Al_2O_3}$		3.22	3.20	3.08	3.35	3.25	3.20	3.19	3.18	—	—	—	—
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$		2.36	2.32	2.32	2.51	2.51	2.47	2.47	2.49	—	—	—	—

* = Parts per million m.e.% = Milligram equivalents per 100 grm of soil † = Percentage composition of the bases

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality		HD. APPILA		Section 3	HD. APPILA			Section 508	
Soil No.		3789	3790	3791	3792	3793	3794	3795	3796
Depth		0–4″	4–12″	12–30″	0–6″	6–18″	18–27″	27–33″	33–36″
Horizon		A	B	BC	A_1	A_2	A_2	B	B
Reaction	pH	8.8	8.6	8.5	8.6	8.4	8.7	8.6	8.6
		%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	2.84	5.91	34.7	8.44	0.46	0.01	0.01	0.02
Mechanical Analysis—									
Coarse Sand		13.9	12.9	7.8	7.4	23.8	31.4	22.3	17.1
Fine Sand		34.6	29.2	19.7	33.5	40.9	42.3	32.9	26.2
Silt		18.1	17.1	9.3	13.7	11.1	12.8	11.2	9.2
Clay		23.0	27.7	22.1	30.4	19.5	11.5	29.4	42.1
Loss on Acid Treatment		4.7	8.1	36.6	10.3	1.5	0.4	0.8	1.4
Moisture		4.8	5.6	4.6	4.9	2.9	1.1	3.9	5.2
Chemical Data—									
Loss on Ignition		6.5	7.7	18.9	9.1	3.7	1.8	3.6	5.0
Organic Carbon	C	1.01	0.86	0.53	1.04	0.63	0.20	0.32	0.41
Nitrogen	N	0.102	0.091	0.059	0.096	0.058	0.026	0.041	0.052
Phosphoric Acid	P_2O_5	0.053	0.047	—	0.046	0.032	—	—	—
Potash	K_2O	0.99	1.02	—	0.76	0.50	—	—	—
Chlorides	as NaCl	0.020	0.021	0.058	0.018	0.023	0.008	0.015	0.020
Reactive Manganese	Mn	250*	—	—	210*	—	—	—	—
		m.e.%			m.e.%	m.e.%	m.e.%	m.e.%	m.e.%
Exchangeable Hydrogen	H	0.2	nil	nil	0.2	0.5	0.7	1.6	1.8

* = Parts per million

m.e.% = Milligram equivalents per 100 grm. of soil

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality	HD. ANNE			Section 478		HD. ANNE			Section 498	
Soil No.	3805	3806	3807	3808	3809	3810	3811	3812	3813	3814
Depth	0–6″	6–14″	14–21″	21–38″	38–44″	0–5″	5–11″	11–24″	24–30″	30–42″
Horizon	A_1	A_2	B_1	B_1	B_2	A_1	A_2	B_1	B_2	B_2C
Reaction pH	8.4	7.9	7.9	8.6	9.2	7.6	9.0	8.8	8.4	8.5
	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	0.19	0.01	0.01	0.02	4.61	0.04	0.01	0.03	0.61	9.89
Mechanical Analysis—										
Coarse Sand	3.9	4.9	2.4	2.6	1.7	0.2	0.0	0.0	0.0	0.1
Fine Sand	41.0	47.0	27.1	24.0	19.2	10.8	8.8	3.0	2.9	2.8
Silt	29.8	25.4	12.2	11.3	13.6	45.5	47.2	22.8	23.9	29.0
Clay	21.5	21.3	51.5	54.1	52.9	23.0	37.2	63.9	61.5	49.5
Loss on Acid Treatment	1.5	0.8	1.5	1.9	6.5	2.1	1.4	2.1	2.8	12.0
Moisture	2.3	1.4	6.6	8.1	8.3	5.0	5.0	10.2	10.8	7.9
Chemical Data—										
Loss on Ignition	4.4	3.0	5.8	5.8	7.0	8.5	5.8	7.0	6.8	10.0
Organic Carbon C	0.73	0.26	0.40	0.26	0.13	2.44	0.94	0.67	0.49	0.27
Nitrogen N	0.089	0.051	0.063	0.050	0.038	0.260	0.117	0.090	0.077	0.064
Phosphoric Acid P_2O_5	0.062	0.044	0.054	0.051	0.050	0.098	0.061	0.069	—	0.104
Potash K_2O	0.88	0.79	1.27	1.37	1.37	1.42	1.59	1.93	—	1.78
Chlorides as NaCl	0.013	0.008	0.013	0.020	0.018	0.021	0.026	0.064	0.112	0.132
Reactive Manganese Mn	580*	—	—	—	—	400*	—	—	—	—
Exchangeable Bases—	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †
Calcium Ca	6.44 60	3.58 57	6.51 38	6.43 29	6.80 29	12.71 53	8.42 41	10.01 30	—	9.12 32
Magnesium Mg	3.05 28	1.74 28	8.40 48	11.90 54	12.07 52	9.07 38	8.99 44	15.97 47	—	14.02 50
Potassium K	1.04 10	0.60 9	1.26 7	1.61 7	1.69 7	1.80 7	1.06 5	2.33 7	—	2.09 7
Sodium Na	0.27 2	0.35 6	1.24 7	2.08 10	2.89 12	0.48 2	2.11 10	5.34 16	—	3.15 11
Total Bases	10.80 100	6.27 100	17.41 100	22.02 100	23.45 100	24.06 100	20.58 100	33.65 100		28.38 100
Exchangeable Hydrogen H	0.7	1.5	3.4	1.4	nil	2.2	0.7	0.3	nil	nil
Percentage Base Saturation	94	81	84	94	100	92	97	99	100	100
Composition of Clay Fraction—										
$\frac{SiO_2}{Al_2O_3}$	3.25	3.19	2.92	2.97	3.12	3.44	3.45	3.45	3.52	3.55
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	2.53	2.46	2.31	2.36	2.47	2.64	2.61	2.60	2.66	2.68

* = Parts per million   m.e.% = Milligram equivalents per 100 grm of soil   † = Percentage composition of the bases

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality	HD. ANNE		Section 473		HD. WHYTE		Section 515		HD. BELALIE			Section 715	
Soil No.	1854	1855	1856	1857	3815	3816	3817	3818	3819	3820	3821	3822	3823
Depth	0 4″	4-9″	9–18″	18–27″	0–5″	5 14″	14–19″	19–25″	0 5″	5–12″	12–30″	30–36″	36–41″
Horizon	A_1	A_2	A_2	B	A	B_1	B_1	B_2C	A_1	A_2	B_1	B_1	B_2C
Reaction .... pH	6.3	6.1	6.9	7.7	7.1	7.4	7.6	8.2	6.7	6.0	7.2	8.3	9.0
	%	%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate $CaCO_3$	tr.	tr.	nil	tr.	tr.	tr.	0.11	8.56	tr.	0.01	0.01	0.01	0.34
Mechanical Analysis													
Coarse Sand	5.5	5.2	5.8	2.6	17.6	14.7	6.1	5.4	8.3	9.0	3.2	8.8	11.8
Fine Sand	47.4	48.6	49.3	34.8	35.9	26.8	12.8	13.5	53.2	48.0	20.6	24.5	36.6
Silt	25.8	23.6	23.8	11.0	16.8	9.3	5.7	6.3	21.4	25.0	12.4	13.4	13.2
Clay	19.6	20.2	18.5	44.1	24.2	41.8	64.4	58.1	13.0	16.5	53.9	46.6	33.3
Loss on Acid Treatment	0.2	0.2	0.2	0.5	1.1	1.5	2.0	11.0	0.8	0.4	1.0	1.1	1.3
Moisture	1.8	1.9	2.8	7.9	3.3	6.2	10.3	8.3	1.4	1.3	8.6	6.9	4.9
Chemical Data—													
Loss on Ignition	3.4	2.9	3.0	5.0	5.4	5.8	7.8	10.8	4.2	2.6	6.4	5.4	4.0
Organic Carbon C	0.61	0.35	0.24	0.31	1.04	0.58	0.64	0.59	1.44	0.51	0.59	0.44	0.20
Nitrogen .... N	0.069	0.052	0.042	0.049	0.102	0.067	0.077	0.074	0.132	0.057	0.073	0.056	0.031
Phosphoric Acid P_2O_5	0.054	0.050	0.044	0.045	0.055	0.050	—	—	0.043	0.037	0.049	—	—
Potash .... K_2O	0.90	0.91	0.94	1.25	0.83	1.06	—	—	0.55	0.66	1.16	—	—
Chlorides as NaCl	0.010	0.015	0.016	0.021	0.011	0.015	0.020	0.020	0.008	0.006	0.015	0.021	0.025
Reactive Manganese Mn	640*	—	—	—	340*	—	—	—	260*	—	—	—	—
Exchangeable Bases—	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.%	m.e.%	m.e.%	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †
Calcium .... Ca	2.24 47	1.89 41	2.04 30	4.07 21	—	—	—	—	4.33 60	1.57 43	6.81 30	—	3.77 21
Magnesium .... Mg	1.26 26	1.65 35	3.16 47	8.19 55	—	—	—	—	1.51 21	1.02 28	12.93 57	—	11.51 63
Potassium .... K	0.98 20	0.68 15	0.66 10	1.35 9	—	—	—	—	1.23 17	0.90 24	1.24 6	—	0.75 4
Sodium .... Na	0.33 7	0.44 9	0.85 13	2.47 15	—	—	—	—	0.18 2	0.20 5	1.57 7	—	2.11 12
Total Bases	4.81 100	4.66 100	6.71 100	16.08 100	—	—	—	—	7.25 100	3.69 100	22.55 100	—	18.14 100
Exchangeable Hydrogen H	4.1	3.3	2.6	2.9	2.6	2.4	2.5	1.0	4.1	4.1	5.4	1.8	nil
Percentage Base Saturation	54	59	72	85					64	47	81	—	100
Composition of Clay Fraction:													
$\frac{SiO_2}{Al_2O_3}$	—	—	—	—	—	—	—	—	3.68	3.53	2.91	—	3.32
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$	—	—	—	—	—	—	—	—	2.80	2.67	2.28	—	2.51

* = Parts per million   m.e.% = Milligram equivalents per 100 grm of soil   † = Percentage composition of the bases

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality		HD. YANGYA Section 316				HD. BUNDALEER Section 134					HD. GILBERT		
Soil No.		3824	3825	3826	3827	3828	3829	3830	3831	3832	36	37	38
Depth		0–6″	6–18″	18–26″	26–36″	0–6″	6–18″	18–28″	28–32″	32–44″	0–8″	8–20″	20–24″
Horizon		A	B	B	BC	A	B	BC	BC	BC	A	B	BC
Reaction	pH	8.0	8.2	8.3	8.8	8.3	8.5	8.6	8.8	8.9	7.7	7.9	8.5
		%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	0.07	0.01	0.09	35.3	0.65	1.99	2.90	13.8	21.4	0.06	0.14	27.3
Mechanical Analysis—													
Coarse Sand		7.4	5.2	5.3	2.2	1.0	3.3	5.0	4.8	4.1	0.6	0.5	0.3
Fine Sand		32.8	24.6	23.0	13.3	38.9	19.8	26.7	25.6	22.2	26.6	17.6	13.1
Silt		20.7	16.4	17.3	8.7	12.6	16.0	8.5	7.3	6.4	19.4	11.5	9.7
Clay		33.1	45.9	46.1	34.2	39.7	50.1	47.0	39.4	38.5	46.4	60.4	42.5
Loss on Acid Treatment		1.5	1.3	1.5	37.4	2.5	3.9	5.1	16.0	23.1	2.1	2.3	29.4
Moisture		5.2	7.5	8.0	5.6	6.4	8.4	8.6	7.3	6.9	5.9	8.6	6.1
Chemical Data—													
Loss on Ignition		5.5	5.3	5.1	18.7	5.7	6.9	6.7	10.5	13.5	6.3	6.7	16.9
Organic Carbon	C	1.23	0.68	0.50	0.36	1.14	1.05	0.74	0.46	0.37	1.50	0.92	0.53
Nitrogen	N	0.108	0.066	0.052	0.038	0.110	0.104	0.077	0.049	0.039	0.122	0.085	0.052
Phosphoric Acid	P_2O_5	0.042	0.037	0.038	—	0.050	0.046	0.042	—	—	0.014	0.038	0.029
Potash	K_2O	0.93	1.20	1.21	—	1.11	1.18	1.04	—	—	1.12	1.30	0.98
Chlorides	as NaCl	0.016	0.015	0.013	0.015	0.020	0.021	0.020	0.016	0.015	0.018	0.018	0.011
Reactive Manganese	Mn	580*	—	—	—	220*	—	—	—	—	—	—	—
Exchangeable Bases—		m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †	m.e.% †	m.e.% †	m.e.% †
Calcium	Ca	17.05 77	19.89 74	20.27 72	—	23.24 74	26.82 74	25.95 74	—	16.88 65	23.38 73	27.70 69	21.15 67
Magnesium	Mg	3.61 16	5.05 19	5.79 21	—	4.73 15	7.09 20	7.10 20	—	7.11 27	6.36 20	10.29 25	8.16 26
Potassium	K	1.42 6	1.24 5	1.49 5	—	3.15 10	1.57 4	1.19 4	—	1.13 4	1.94 6	1.65 4	1.13 4
Sodium	Na	0.28 1	0.49 2	0.66 2	—	0.44 1	0.59 2	0.86 2	—	1.14 4	0.36 1	0.81 2	0.90 3
Total Bases		22.36 100	26.67 100	28.21 100	—	31.56 100	36.07 100	35.10 100	—	26.26 100	32.04 100	40.45 100	31.34 100
Exchangeable Hydrogen	H	1.4	1.4	1.1	nil	0.4	0.3	0.2	nil	nil	2.5	2.7	0.3
Percentage Base Saturation		94	95	96	100	99	99	100	100	100	93	94	99

* = Parts per million   m.e.% — Milligram equivalents per 100 grm of soil   † = Percentage composition of the bases

TABLE II (continued)

The Mechanical and Chemical Analyses of Typical South Australian Red-brown Earth Profiles

Locality		HD. REYNOLDS			Section 220E		HD. GILBERT			Section 1157	
Soil No.		3833	3834	3835	3836	3837	3709	3710	3711	3712	3713
Depth		0 3"	3–9"	0–4½"	4½–18"	18–30"	0–5"	5 14"	14–27"	27–36"	36–42"
Horizon		A	B	A	B	B	A_1	A_2	B	BC	BC
Reaction	pH	8.2	8.1	7.9	7.8	8.5	6.4	7.3	8.4	8.8	9.0
		%	%	%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	0.49	0.07	0.01	0.01	0.11	nil	tr.	0.01	0.02	0.09
Mechanical Analysis—											
Coarse Sand		5.8	6.2	12.7	3.7	2.8	17.8	16.9	8.2	13.6	23.8
Fine Sand		26.3	24.9	33.7	10.8	9.5	58.5	55.2	32.3	43.0	31.7
Silt		19.0	15.4	17.4	7.1	7.5	15.2	16.7	9.5	8.8	8.1
Clay		38.1	44.1	30.2	67.1	69.5	6.6	10.3	42.6	29.0	31.2
Loss on Acid Treatment		2.8	2.3	1.0	1.4	1.7	0.3	0.1	1.1	1.3	1.7
Moisture		6.1	7.5	3.9	10.3	10.7	0.7	0.9	6.9	3.8	4.3
Chemical Data—											
Loss on Ignition		9.0	7.3	5.2	7.6	7.3	2.0	1.4	4.6	3.8	3.9
Organic Carbon	C	2.73	1.76	1.25	0.76	0.53	0.68	0.12	0.22	0.11	0.08
Nitrogen	N	0.219	0.132	0.112	0.089	0.070	0.049	0.017	0.031	0.019	0.016
Phosphoric Acid	P_2O_5	0.061	0.045	0.049	0.060	—	0.030	0.012	—	—	—
Potash	K_2O	0.94	0.88	0.80	1.44	—	0.23	0.29	—	—	—
Chlorides	as NaCl	0.020	0.018	0.011	0.023	0.031	0.005	0.008	0.023	0.025	0.036
Reactive Manganese	Mn	—	—	520*	—	—	34*	—	—	—	—
		m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%
Exchangeable Hydrogen	H	1.3	1.3	2.2	4.4	1.8	2.7	0.8	1.2	0.4	nil

* = Parts per million

m.e.% = Milligram equivalents per 100 grm. of soil

TABLE III

The Mechanical and Chemical Analyses of some Greyish-brown Soils occurring in the Red-brown Earth Zone

Locality		HD. GILBERT	Section 294				HD. BELALIE	Section 185			HD. BELALIE	Section 185	
Soil No.		3718	3719	3720	3721	3722	3778	3779	3780	3781	3782	3783	3784
Depth		0–4″	4–12″	12–24″	24–36″	36–54″	0–6″	6–13″	13–21″	21–36″	0–5″	5–10″	10–18″
Horizon		A	B_1	B_2	B_2C	B_2C	AB	BC	C	C	AB	C	C
Reaction	pH	8.6	9.0	9.2	9.3	9.2	8.4	8.5	8.5	9.0	8.4	8.8	9.5
		%	%	%	%	%	%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	2.50	0.42	1.84	7.62	5.16	8.42	16.2	26.0	29.0	10.4	22.3	46.2
Mechanical Analysis—													
Coarse Sand		5.9	5.0	5.6	6.6	5.3	1.4	1.5	0.8	0.5	2.6	2.3	3.1
Fine Sand		29.7	22.5	20.8	22.6	23.3	28.4	36.1	32.6	35.5	44.9	39.4	27.7
Silt		10.7	8.6	7.2	7.2	8.8	33.1	30.2	27.5	27.7	22.4	18.1	14.0
Clay		41.7	53.6	54.4	46.0	46.0	13.8	12.9	9.1	3.5	12.8	11.3	4.3
Loss on Acid Treatment		4.0	2.9	4.1	8.8	5.9	10.3	18.3	28.1	30.8	12.3	25.0	47.9
Moisture		7.2	9.8	9.8	8.0	9.5	2.2	1.8	1.2	0.3	2.5	2.3	0.9
Chemical Data—													
Loss on Ignition		7.3	6.2	6.4	8.6	6.8	9.0	11.2	14.8	15.1	10.7	14.5	22.8
Organic Carbon	C	1.22	0.89	0.76	0.55	0.30	1.43	0.80	0.57	0.14	1.94	1.19	—
Nitrogen	N	0.118	0.084	0.067	0.042	0.022	0.186	0.126	0.095	0.054	0.228	0.151	0.076
Phosphoric Acid	P_2O_5	0.050	0.029	0.027	—	—	0.177	0.162	—	—	0.166	—	—
Potash	K_2O	1.04	1.19	1.18	—	—	0.95	0.85	—	—	0.70	—	—
Chlorides	as NaCl	0.016	0.025	0.038	0.073	0.157	0.013	0.016	0.069	0.048	0.020	0.091	0.178
Reactive Manganese	Mn	70*	—	—		—	440*	—	—		—	—	—
Exchangeable Bases		m.e.% †	m.e.% †	m.e.% †	m.e.%	m.e.% †	m.e.%	m.e.%					
Calcium	Ca	26.62 77	28.16 68	18.48 46	—	6.87 21	—	—	—	—	—	—	—
Magnesium	Mg	5.14 15	8.42 21	12.19 31	—	11.36 34	—	—	—	—	—	—	—
Potassium	K	2.01 6	1.54 4	1.61 4	—	1.54 4	—	—	—	—	—	—	—
Sodium	Na	0.58 2	3.04 7	7.75 19	—	13.66 41	—	—	—	—	—	—	—
Total Bases		34.35 100	41.16 100	40.03 100	—	33.43 100	—	—	—	—	—	—	—
Exchangeable Hydrogen	H	0.3	nil	nil	nil	nil	0.3	0.3	nil	nil	—	—	—
Percentage Base Saturation		99	100	100	100	100	—	—	100	100	—	—	—
Composition of Clay Fraction—													
$\frac{SiO_2}{Al_2O_3}$		3.56	3.55	3.58	3.61	3.57	—	—	—	—	—	—	—
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$		2.97	2.94	2.97	2.99	2.97	—	—	—	—	—	—	—

* = Parts per million m.e.% = Milligram equivalents per 100 grm of soil † = Percentage composition of the bases

ADDITIONS TO THE FLORA OF SOUTH AUSTRALIA NO. 36

BY *J. M. BLACK*

Summary

LILIACEAE

Xanthorrhoea quadrangulata, F. v. *M.* Grown from seed in Dr. E. C. Black's garden at Magill and fruiting in second year (December, 1937). Capsule brown, glossy, 1-seeded, rarely 2- or 3-seeded, about 15 mm. long, on a conical ribbed rigid stipes about 5 mm. long, each of the three valves ending in a pungent mucro; seed compressed, triquetrous, dull-black, about 10mm long. At this early stage the plant has no stem, the older leaves lying flat on the ground.

ADDITIONS TO THE FLORA OF SOUTH AUSTRALIA [1]

No. 36

By J. M. Black, A.L.S.

[Read 12 May 1938]

Plates III and IV

Gramineae

Stipa elatior, Hughes. Near Clare, *E. C. Black.*

Liliaceae

Xanthorrhoea quadrangulata, F. v. M. Grown from seed in Dr. E. C. Black's garden at Magill and fruiting in second year (December, 1937). Capsule brown, glossy, 1-seeded, rarely 2- or 3-seeded, about 15 mm. long, on a conical ribbed rigid stipes about 5 mm. long, each of the three valves ending in a pungent mucro; seed compressed, triquetrous, dull-black, about 10 mm. long. At this early stage the plant has no stem, the older leaves lying flat on the ground.

Proteaceae

Hakea chordophylla, F. v. M. Fraser River 4 miles E. of MacDonald Downs, C.A., 1930, *J. B. Cleland.* Wrongly recorded as "*G. chordophylla,*" p. 242 of last year's Transactions.

Grevillea stenobotrya, F. v. M. Between Alice Springs and the Granites, C.A., Sept. 1936, *E. C. Black.* The fruit is at first smooth and dark-reddish-brown; after a time this dark epicarp breaks away in pieces and discloses a pale-brown pitted endocarp. *G. livea,* Ewart et Archer, Fl. N. Terr. 84, t. 8 (1917), is apparently a synonym of *G. stenobotrya,* F. v. M. (1875).

Cruciferae

Blennodia blennodioides (F. v. M.) Druce in Rept. Bot. Exch. Club, 1916, 609 (1917). Hermannsburg, C.A., Aug. 1929, *J. B. Cleland.* First record for Central Australia—*Erysimum blennodioides,* F. v. M. in Linnaea 25: 367 (1852); *Blennodia lasiocarpa,* F. v. M. in Trans. Phil. Soc. Vict. 1: 100, in adnot. (1855). This last name was adopted by Bentham in the Fl. Aust., but is not correct under the International Rules of 1905 and 1930, which only forbid the use of specific names "when they exactly repeat the generic name."

Blennodia brevipes, F. v. M. in Trans. Phil. Soc. Vict. 1: 100 (1855) in adnot. This small annual, found in all the southern States except Tasmania, possesses the following synonyms:—*Erysimum brevipes,* F. v. M. in Linnaea

[1] Several of these notes refer to Central Australian species which have not so far been found in South Australia.

25:367 (1852); *Alyssopsis Drummondii,* Turcz. in Bull. Soc. Nat. Mosc. 27:2:291 (1854); *Sisymbrium brachypodum,* F. v. M., Fragm. 7:20 (1869); *Harmsiodoxa brevipes* (F. v. M.) O. E. Schulz in Engl. Pflanzenr., Heft 86:260 (1924); *Blennodia Drummondii* (Turcz.) C. A. Gardner, Enum. Pl. Aust. Occ. 45 (1930).

LEGUMINOSAE

Cassia oligophylla, F. v. M. The Granites, C.A., Aug. 1936, *J. B. Cleland.* First record for Central Australia. Previously collected in north-west of Western Australia and in western Queensland.

Leaflets silvery with a close appressed pubescence; pods 3-5 cm. long, by 12-16 mm. broad. The flowers are in 6-flowered umbels, not in "short racemes." *C. desolata* also has the flowers usually in umbels.

Acacia Kempeana, F. v. M. Neepabunna, Flinders Range, 1937, *J. B. Cleland.* A new locality.

Psoralea pustulata, F. v. M. The Granites, C.A., Aug. 1936, *J. B. Cleland.* First record for Central Australia. The specimen agrees with Bentham's description, except that the terminal leaflet is lanceolate-oblong and 4-7 cm. long.

Jacksonia anomala, Ewart et Morrison. Between the Granites and Thomson's Waterhole, C.A., Aug. 1936, *J. B. Cleland.* The two keel-petals are not merely separate but are distant from each other and placed immediately against the inner face of the two narrow wings (pl. iv, fig. 1).

Indigofera Georgei, E. Pritzel in Engl. Bot. Jahrb. 35:268 (1904) = *I. boviperda,* Morrison in Journ. Bot. 50:166 (1912).

Centr. Aust.—The Granites; Archibald's Soak, near Coniston Station; W. of Brook's Soak, June 1936, *J. B. Cleland.*

This grey-tomentose plant, recognisable by its constantly five obovate leaflets and its small red flowers, was also found on the Lander Creek by G. F. Hill in 1911 and recorded (as *I. boviperda*) by Ewart and Davies in Fl. N. Terr., p. 142.

Morrison distinguishes his *I. boviperda* from *I. Georgei* by stating that "the leaves and pods are shorter and the racemes attain a greater length." Neither of these distinctions appears valid. Both descriptions agree as to the number, shape and size of the leaflets. Pritzel says the racemes are 2-5 cm. long, his specimens being in flower, with unripe pods ("legumen submaturum") 3 cm. long. In Morrison's specimens the petals had fallen, the pods were ripe and 12-28 mm. long, and the racemes were 2-19 cm. long. Both these types came from the central and northern parts of Western Australia. In our specimens from Central Australia the leaflets are usually 6-12 mm. long, the long terminal ones rarely reaching 25 mm.; the racemes are short and dense at first, but in fruit become loose and lengthen to 15 cm. or more. The ripe pods are 2-4 cm. long, with a rigid mucro. The caducous bracts are broad-lanceolate and shorter than the flowers they subtend.

Indigofera linifolia, Retz. The Granites, C.A., Aug. 1936, *J. B. Cleland.* Already recorded from the MacDonnell Ranges.

Indigofera hirsuta, L. Pine Hill (north of MacDonnell Ranges and near Hanson River), C.A., Aug. 1936, *J. B. Cleland*. The hairs of the stem and of the leaf-rhachis are less spreading than in North Australian and Asiatic specimens. Standard pubescent on back and keel pubescent on midrib; bracts about 5 mm. long, oblanceolate, channelled above.

Indigofera viscosa, Lamk. Coniston Station; the Granites, C.A., Aug. 1936, fruiting, *J. B. Cleland*. Recorded by Tate for Hermannsburg.

Crotalaria crispata (F. v. M.) Benth. The Granites, C.A., Aug. 1936, *J. B. Cleland*. First record for Central Australia.

Tephrosia phaeosperma, F. v. M., ex Bentham, 20 miles south of the Granites, C.A., Aug. 1937, *J. B. Cleland*. First record for Central Australia.

Tephrosia eriocarpa, Benth. The Granites, C.A., Aug. 1936, *J. B. Cleland*. First record for Central Australia. In our specimens the flowers are mostly in racemes, which in fruit become 15 to 20 cm. long.

Ptychosema stipulare nov. sp. Plantula procumbens, omnino (corollâ ovarioque exceptis) patenti-pilosa; caules plures, graciles, 10-20 cm. longi, dichotome ramosi; folia distantia, 3-foliolata; foliola brevissime petiolulata, obovata, 4-6 mm. longa; petioli filiformes, 5-10 mm. longi; stipulae conspicuae, orbiculari-acutae, circa 4 mm. longae; pedunculi, axillares, 1-flori, 15-20 mm. longi, prope apicem articulati et bracteati; bractea linearis, pedicellum brevem superans; calyx 5 mm. longus, lobis lanceolatis, tubum subaequantibus, duobus superioribus brevioribus; bracteolae 2, tubum calycis aequantes; vexillum unguiculatum, circa 7 mm. longum, cum alis brevioribus purpureo-punctatum; carina flava, vexillo paulo brevior; stamina in tubum fissum connata; ovarium planum, glabrum, 6-7-ovulatum, stylo brevi; legumen immaturum planum, glabrum lineari-oblongum, circa 25 cm. longum, 6-7 mm. latum, conspicue stipitatum (tab. iii, fig. 4).

Near Bundoona railway station, C.A., Aug. 1936, *J. B. Cleland*.

Resembles *P. trifoliolatum*, F. v. M., in habit, but differs in its covering of spreading hairs, instead of being almost or quite glabrous; also in the leaflets, which are not obcordate, and especially in the conspicuous stipules, which are orbicular instead of small and linear. The upper lip of the calyx is not almost truncate-emarginate, as in *P. trifoliolatum*, but consists of the two upper lobes, which are lanceolate, like the three lower ones, although united for a short distance. The colour of the flowers is also different, the standard and wings being purple-dotted, while in *P. trifoliolatum* they are yellow, and in the latter species the keel is longer than the standard.

Ptychosema trifoliolatum, F. v. M. Coniston, C.A., Aug. 1936, *J. B. Cleland*. Recorded by Tate from near the James Range, C.A.

Desmodium parvifolium, DC. (pl. iii, fig. 1). The drawing is from a specimen collected by Leichhardt at Archer's Station, Queensland, and lent by the Victorian National Herbarium. Not yet found in Central Australia. The single leaflets are quite as numerous as the ternate ones; the hairs of the pod are not hooked.

Desmodium Muelleri, Benth. (pl. iii, fig. 2). The drawing is from a fruiting specimen collected by Dr. Maurice Holtze, probably near Darwin, in 1890, and kindly lent by the Government Botanist of Victoria, Mr. F. J. Rae. Another specimen, from the Upper Victoria River, *F. Mueller,* also obtained on loan, has unripe pods and longer leaflets, $1\frac{1}{2}$-3 cm. long. The leaflets in both specimens are conspicuously reticulate and the hairs of the pods are hooked. Not yet found in Central Australia. The late Prof. Ewart records (Fl. N. Terr. 150) specimens collected on the Adelaide River, N.A., with pods indented on both sutures, and which he refers to *D. Muelleri.* They may be *D. neurocarpum.*

Desmodium neurocarpum, Benth. (pls. iii fig. 3, and iv fig. 2). Archibald's Soak (between Coniston and the Granites), C.A., Aug. 1936, *J. B. Cleland.* First record for Central Australia. In the specimens from Archibald's Soak the plant is small and apparently procumbent, the leaflets are more often solitary than three, mostly broad-oblong, 10-18 mm. long, 5-10 mm. broad. In the type-specimen (pl. iv, fig. 2), collected by Mueller on the Upper Victoria River and kindly lent by the Victorian National Herbarium, the leaflets are 15-35 mm. long and 5-8 mm. broad. In all specimens the terminal leaflet is the longest and the reticulation is prominent, especially on the undersurface. The fruiting peduncles are very slender and attain a length of 10-25 cm. Very near *D. Muelleri,* Benth., differing chiefly in the pod, which has the upper margin indented between the articles, which are rather more strongly reticulate, and the hairs along the margin are straight, while in *D. Muelleri* the upper margin is straight or almost so and the hairs are hooked at summit.

It is probable that our Central Australian specimens are the same as *D. neurocarpum,* Benth. var. *queenslandicum,* Domin in Bibl. Bot. 89: 768, which is described as having shorter and broader leaflets than the type and very slender prostrate branches. The variety is recorded by Domin from the Queensland coasts and from near Hughenden, on the Flinders River.

Malvaceae

Hibiscus

The position of *Hibiscus brachychlaenus* and its immediate allies was incorrectly defined in the Fl. S. Aust. 381 (1926) and an attempt is here made to place them more satisfactorily.

A. Leaves all undivided, oblong-lanceolate, 3-6 cm. long, 15-25 mm. broad, tomentum dense, of stellate hairs about $1\frac{1}{2}$ mm. across; epicalyx of 7-10 free bracteoles only half as long as the calyx-tube; calyx 15-20 mm. long; peduncles swollen below calyx to the breadth of the calyx-tube; style branches free .... *H. brachychlaenus* 1

A. Leaves mostly 3-5-lobed; tomentum less dense, of stellate hairs about $\frac{1}{2}$ mm. across; epicalyx of 7-10 free bracteoles about as long as the calyx-tube; peduncles not swollen below calyx.

B. Leaves all 3-5 lobed; style-branches twisted and connate.

C. Leaves almost orbicular in outline, to 5 cm. long and broad, the lobes ovate, 15 25 mm. broad, coarsely crenate in upper part, strongly nerved below; calyx 16-25 mm. long .... *H. Pinonianus* 2

C. Leaves ovate in outline, the lobes oblong-cuneate, narrow (4-10 mm. broad), coarsely toothed; calyx 20-25 mm. long .... *H. Drummondii* 3

B. Uppermost leaves undivided, linear-lanceolate, 3-5 cm. long, 8-12 mm. broad, crenate in upper part; other leaves deeply divided into 3 oblong-cuneate or almost obovate, more or less toothed lobes 8-12 mm. broad; calyx about 15 mm. long; style-branches free .... *H. intraterraneus* 4

1 *H. brachychlaenus,* F. v. M. Fragm. 3:5 (1862).—*H. microchlaenus,* F. v. M. Fragm. 2: 116, *nomen nudum* (1861).

C. Aust.—The Granites, Aug. 1936, *J. B. Cleland.*

N. Aust.—Upper Victoria River.

W. Aust.—Nichol Bay; Fortescue and Fitzroy Rivers; Rawlinson Range.

Queensland—Cape River.

Tate gives this species for Eyre Peninsula, but I have seen no specimen from that locality.

2 *H. Pinonianus,* Gaudich. in Freyc. Voy. Bot. 476, t. 100 (1826).

S. Aust.—Between Wynbring and Ooldea, April 1917, *S. A. White.*

C. Aust.—Mount Denison, *J. M. Stuart.*

W. Aust.—Sharks Bay, *Gaudichaud;* Victoria Desert, *R. Helms.*

3 *H. Drummondii,* Turcz. in Bull. Mosc, 1, 195 (1858).

S. Aust.—Minnipa, E.P., Nov. 1915, *J. M. B.;* N. of Murat Bay, Dec. 1917, *B. P. Bowering.*

W. Aust.—Murchison and Greenough Rivers.

4 *H. intraterraneus,* J. M. Black in Trans. Roy. Soc. S. Aust., 49:274 (1925).

S. Aust.—Everard, Musgrave and Birksgate Ranges, *R. Helms, S. A. White, H. H. Finlayson.*

C. Aust.—MacDonnell Ranges, *R. Tate.*

Solanaceae

Solanum phlomoides (A. Cunn.) Benth. The Granites, C.A., Aug. 1936, *J. B. Cleland.* First record for Central Australia. Only differs from Bentham's description in the leaves (5-9 cm. long by 2½-3½ cm. broad) being all obtuse and none acuminate. The very large globular or ovoid fruit (3-4 cm. long) is exceeded by the narrow-pointed calyx-lobes, which are about 4 cm. long, the whole calyx, including the broad tube, being about 5 cm. long or rather more. The seeds are very numerous and black. The fruit is (in our specimens) only produced by the lowest flower of each raceme, the upper flowers being apparently male only and caducous. The berry is eaten by the natives.

Solanum nemophilum, F. v. M. The type, from Queensland, had no prickles, and the plant was so described; owing to this error it was re-described by me as

S. centrale in Trans. Roy. Soc. S. Aust., 58: 180, t. 11, fig. 4 (1934). Almost all our specimens show prickles, sometimes rather numerous, on the branches. This species was collected by H. H. Finlayson in January 1934, 60 miles south of Ernabella, in the Musgrave Ranges—the only record for South Australia—and the specimen was compared with the type in the Victorian National Herbarium.

STYLIDIACEAE

Stylidium inaequipetalum nov. sp. Plantula perennis, 7-14 cm. alta; folia omnia basilaria, crassiuscula, spathulata, obtusa vel subacuta, glabra, 1½-3 cm. longa, apice 2-4 mm. lata, in rosulam densam conferta; scapi 4-7, graciles, erecti, pilis glanduliferis conspersi, paniculam laxam thyrsoideam 5-9 cm. longam gerentes, bracteis exceptis efoliati; flores racemosi vel superiores cymosi; bracteae herbaceae, ovato-lanceolatae, saepe oppositae, 2-3 mm. longae; pedicelli circa 2 mm. longi; receptaculum circa 3 mm. longum, parce glanduloso-pubescens; sepala libera, 1 mm. longa; corollae lobi valde dissimiles, duo posteriores crassi, cuneati, apice truncati, circa 3 mm. longi, duo anteriores minores, circa 1-1½ mm. longi; labellum ovatum, minimum, ad basin bicorniculatum; capsula obconica, striata, 3½-4 mm. longa, 1½ mm. lata, fere unilocularis; semina minuta, orbicularia, circa 15 (tab. iv, fig. 3).

Central Australia—Near Ayers Rock, June 1937, *J. B. Cleland.*

Belongs to Bentham's section *Spathulatae* and in aspect resembles *S. assimile*, R. Br., but differs in the very unequal corolla-lobes, the two posterior ones being two to almost three times as long as the two anterior; in the sparse glandular hairs of the inflorescence; in the ovate-lanceolate subacute bracts about as long as the pedicels, and in the shorter capsule. In *S. assimile* the corolla-lobes are equal, the inflorescence is densely pubescent, the bracts are linear, obtuse and scarcely half as long as the pedicels, and the capsule is 6 mm. long.

DESCRIPTION OF PLATES

PLATE III

Fig. 1 *Desmodium parvifolium*:—*A*, flowering and fruiting branch; *B*, summit of raceme, showing flower and bracts enclosing buds; *C*, leaf; *D*, pod.

Fig. 2 *Desmodium Muelleri*:—*E*, fruiting branch; *F*, pod.

Fig. 3 *Desmodium neurocarpum*:—*G*, two solitary leaflets and raceme in early budding stage; *H*, summit of raceme; *I*, flower; *J*, pod. (From Archibald's Soak, C.A.)

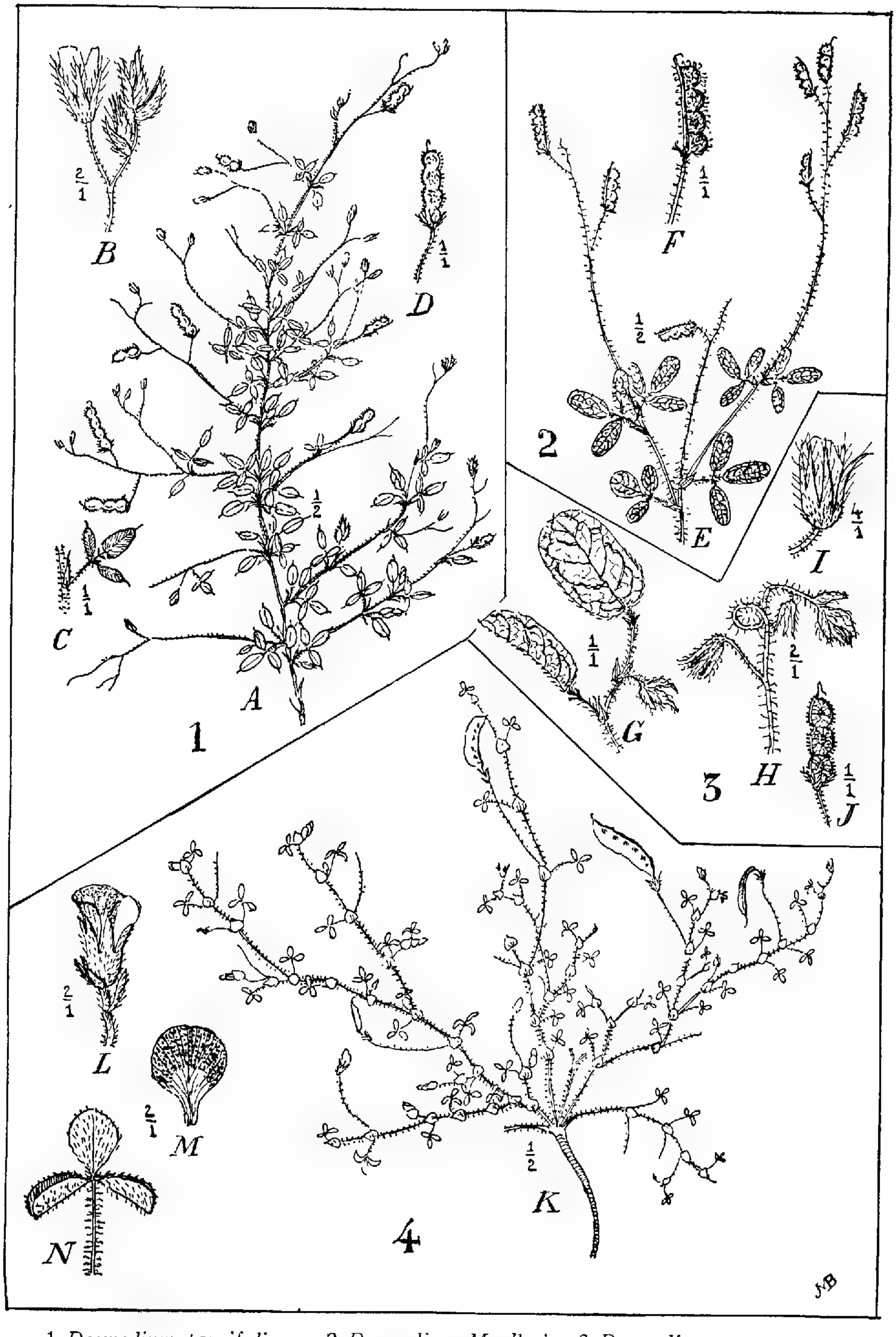
Fig. 4 *Ptychosema stipulare*:—*K*, plant; *L*, flower; *M*, standard; *N*, leaf.

PLATE IV

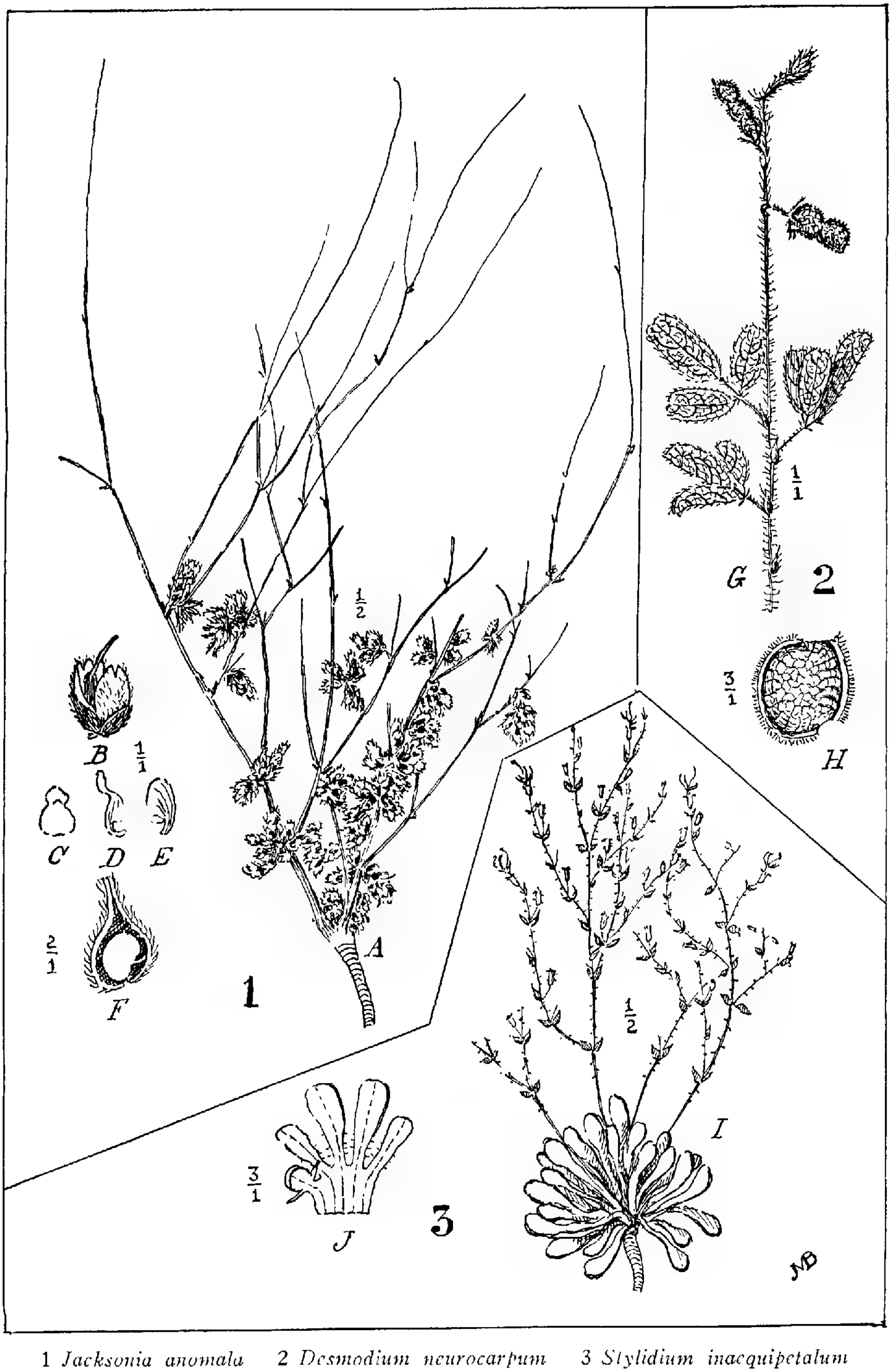
Fig. 1 *Jacksonia anomala*:—*A*, part of plant; *B*, flower; *C*, standard; *D*, one of the wings; *E*, one of the keel petals; *F*, one valve of capsule and seed.

Fig. 2 *Desmodium neurocarpum*:—*G*, fruiting branch; *H*, lowest article of pod. (From type-specimen.)

Fig. 3 *Stylidium inaequipetalum*:—*I*, plant; *J*, corolla spread open.



1 *Desmodium parvifolium* 2 *Desmodium Muelleri* 3 *Desmodium neurocarpum*
4 *Ptychosema stipulare*



1 *Jacksonia anomala* 2 *Desmodium neurocarpum* 3 *Stylidium inaequipetalum*

AN ACCOUNT OF SOME FILARIAL PARASITES OF AUSTRLAIAN MARSUPIALS

BY HARVEY T. JOHNSTON AND PATRICIA M. MAWSON

Summary

The collection of Filarial parasites from Australian marsupials at present under consideration was obtained chiefly in Queensland, New South Wales and Central Australia. References to recorded occurrences of these and other entozoan from this order of mammals in the Australian region were brought together by one of us (Johnston, 1909, 191 1, 1916), but many were listed merely as Filaria sp. Oldham (1933) gave a list of the entozoa reported from Australian and American marsupials.

AN ACCOUNT OF SOME FILARIAL PARASITES OF AUSTRALIAN MARSUPIALS

By T. Harvey Johnston and Patricia M. Mawson
Zoology Department, University of Adelaide

[Read 12 May 1938]

The collection of Filarial parasites from Australian marsupials at present under consideration was obtained chiefly in Queensland, New South Wales and Central Australia. References to recorded occurrences of these and other entozoa from this order of mammals in the Australian region were brought together by one of us (Johnston, 1909, 1911, 1916), but many were listed merely as *Filaria* sp. Oldham (1933) gave a list of the entozoa reported from Australian and American marsupials.

In the present paper four species of *Dipetalonema* are described as new *(D. dasyuri, D. rarum, D. annulipapillatum* and *D. tenue),* and an account is given of *D. roemeri* (Linstow), *D. spelaea* (Leidy), and *D. trichosuri* (Breinl). Brief reference is also made to female specimens, listed as *Dipetalonema* sp., and *Filaria* (s.l.) spp., from four different host species. Of the filariae already described from Australian or New Guinea marsupials, three species have not been identified amongst our material—*Breinlia dendrolagi* Solomon, 1933, described from *Dendrolagus inustus* (New Guinea); *Filaria dentifera* Linstow, 1898, from *Trichosurus vulpecula* (Queensland); and *Dipetalonema capilliforme* Baylis, 1934, from *Dasyurus hallucatus* (North Queensland).

The various parasites studied in the present paper are listed under their respective hosts as follows:—

Macropus major Shaw—*Dipetalonema roemeri* (Burnett River, Queensland).

Macropus robustus Gould—*D. roemeri* (Cockatoo Creek and Mount Liebig, Central Australia); *D. tenue* n. sp. (Cockatoo Creek and Mount Liebig, Central Australia).

Macropus parryi Bennett—*D. roemeri* (Burnett River).

Macropus melanops Gould—*D. roemeri* (North Western Australia).

Macropus dorsalis Gray—*D. annulipapillatum* n. sp. (Burnett River).

Macropus ualabatus Less. and Garn.—*D. roemeri* (Lower Hawkesbury, New South Wales).

Macropus welsbyi Longman—*D. roemeri* (Stradbroke Island, South Queensland).

Dendrolagus lumholzii Collett—*Dipetalonema* sp. (? *roemeri)* (North Queensland, from Melbourne Zoological Gardens).

Dendrolagus bennettianus De Vis—*D. spelaea* (North Queensland, from Sydney Zoological Gardens).

Petrogale penicillata Gray—*D. spelaea* (Burnett River).

Onychogale frenata Gould—*Dipetalonema annulipapillatum* n. sp. (Burnett River); *D. rarum* n. sp. (Victoria); *D. roemeri* (Burnett River).

Trichosurus vulpecula Kerr—*D. trichosuri* (Burnett River).

Trichosurus caninus Ogilby—*Filaria* (s.l.) sp. (Townsville, Gosford, Lower Hawkesbury River, New South Wales).

Potorous tridactylus Kerr—*Filaria* (s.l.) sp. (Dorrigo, New South Wales).

Dasyurus maculatus Kerr—*Filaria* (s.l.) sp. (Brisbane).

Dasyurus viverrinus Shaw—*Dipetalonema dasyuri* n. sp. (Victoria).

The last-named two hosts belong to the Polyprotodontia, all the others to the Diprotodontia.

The host name *Macropus major* has been used instead of *M. giganteus*, of which the former has long been regarded as a synonym. The confusion regarding the correct name of the Great Kangaroo has been discussed by Iredale and Troughton, who have pointed out that *M. major* Shaw is the correct name for it. *M. giganteus* of Erxleben and of Zimmermann belongs to the species seen by Captain Cook in the vicinity of what is now Cooktown, North Queensland, this species being a much smaller form, in fact, a wallaby, *Wallabia cangaru* Muller, 1776, whose range extends northwards to Cape York Peninsula (Iredale and Troughton, Mem. Austr. Museum, **6**, 1934, 55; Rec. Austr. Museum, **20**, (1), 1937, 67-71). In our paper we have not utilized the subdivisions of the old genus *Macropus*. We take the opportunity to correct an error in Linstow's paper (1898) dealing with some parasites collected in the Burnett River region by Semon: the name *Dasypus hallucatus* should be *Dasyurus hallucatus*, sloths *(Dasypus)* being absent from Australia. The parasite referred to by Linstow was a larval nematode, recorded, perhaps incorrectly, as *Ascaris* sp.

We desire to acknowledge assistance in regard to material from the late Dr. T. L. Bancroft and from his daughter, Dr. J. M. Mackerras, for specimens from the Eidsvold district, Upper Burnett River, Queensland; Mr. A. S. LeSouef, Director, Taronga Zoological Park, Sydney, for worms from *Dendrolagus* and *Potorous;* Professor O. W. Tiegs, University of Melbourne, for specimens from *Dasyurus viverrinus;* and our colleague, Professor J. B. Cleland, for parasites from *Macropus melanops*. The remaining material was collected by the senior author, much of it during the various anthropological expeditions to Central Australia (1929-1937).

Types of new species have been deposited in the South Australian Museum, Adelaide.

Wehr (1935, 87) erected the family Dipetalonematidae (Syn. Dirofilariidae Sandground) to receive two subfamilies, Dipetalonematinae (to include Onchocercinae Leiper as well as Loainae and Setariinae Yorke and Maplestone (in part), and Dirofilariinae (a new subfamily for *Dirofilaria* and *Loa)*. Chitwood and Chitwood (1937) have accepted, in part, Wehr's classification. We regard Dipetalonematidae as a synonym of Sandground's family, which has priority. We follow Baylis (1934) in using *Dipetalonema* instead of *Acanthocheilonema*.

Dipetalonema dasyuri n. sp.

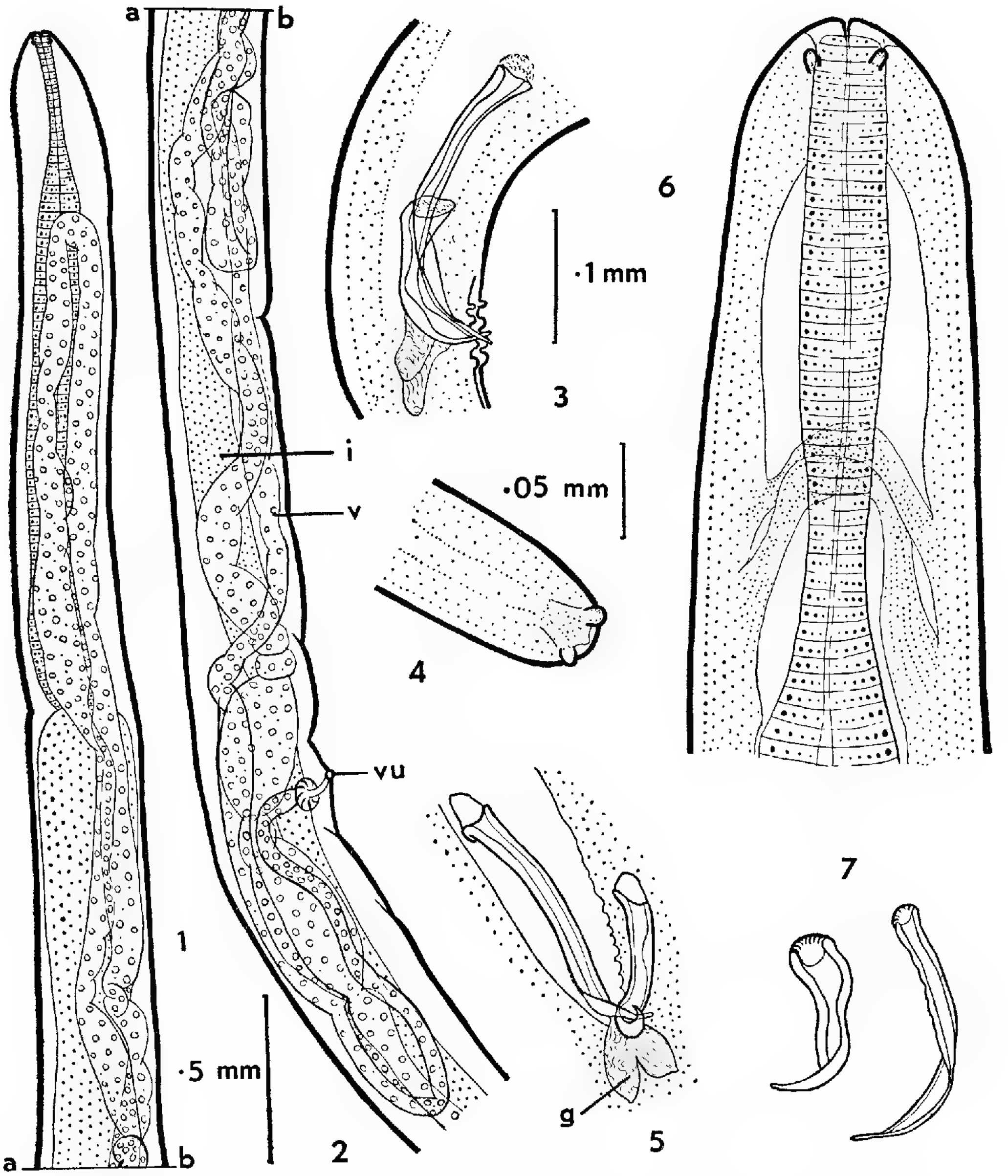
Figs. 1-7

The specimens occurred in large numbers in the body cavity of a "native cat," *Dasyurus viverrinus*, from Victoria. They are long, slender and much coiled. The head is the shape of a truncated cone. There is a tapering tail on which are a pair of sub-terminal papillae. A little back from the anterior extremity are two pairs of large papillae, 0·008 mm. long in the male.

The male attains a length of 20 to 40 mm., and a maximum breadth of 0·17-·26 mm. The head at its widest part is 0·1-·13 mm. wide, and the breadth taken just in front of the cloaca 0·092-·1 mm. The cuticle at about the middle of the body is 2·7 μ thick. The nerve ring is 0·16-·22 mm. from the anterior end. The tail region is coiled in a close spiral of three or four turns. The cloaca is 0·4-·5 mm. from the posterior end, so that the tail is one seventy-fifth of the body length. Around the cloaca are four pairs of papillae, two pre-anal and two post-anal. The spicules are unequal, one being 0·12 mm. and the other 0·2 mm. long. They are of approximately the same shape, cylindrical at the upper or proximal end, spatulate and curved at the distal end, to terminate in a point which is more drawn out in the longer spicule. The testis tubule begins in a swollen portion just posterior to the oesophagus, and is straight for some distance, then coiled. The wide oesophagus consists of an anterior narrower portion, 0·29 to ·32 mm. in length, and a longer wider region 1·1 to 1·2 mm. in length, *i.e.*, about one twenty-eighth of the body length. The straight intestine is relatively wider in the male.

The female dimensions vary considerably with age. The adult is 83 to 97 mm. long, with a maximum breadth of 0·36 to ·37 mm. The head is 0·2 mm. wide, and the cloacal region 0·12-·15 mm. The tail is 0·35 to ·7 mm. and bears, like the male, a pair of subterminal papillae, 0·01 mm. long. The cuticle is 13-19 μ. The nerve ring is about 0·21 mm. from the head end. The anterior part of the oesophagus is about 0·28-·38 mm., and the longer succeeding portion 1·7-2·1 mm., *i.e.*, about one forty-sixth of the body length. The vagina is much coiled in the adult, extending forward almost to the anterior end, then bending back and curving around the position of the vulva, ending in a muscular enlargement from which a narrow tube leads to the exterior. The vulva in the adult female divides the body from head to tail in the ratio 1 : 15, in young females the ratio is 1 : 12. The vagina leads into the uterus and this divides into two uteri which become continuous with the oviducts towards the posterior end. The coils of the ovarian tubes extend almost to the tip of the tail. The uterus is packed with eggs, and among these was found one larva. The eggs are 25 μ by 21·5 μ, and the larva 0·15 mm. long and ·009 mm. wide.

The species differs from *D. roemeri* and *Filaria australis* in having subterminal papillae, also in the number and arrangement of the anal papillae in the male, and in the dimensions of the worms; from *F. dentifera* Linstow in the absence of a dorsal papilla on the head, in being much shorter (especially the males), in the position of the vulva, and in the number of cloacal papillae; from



Figs 1-7

Figs. 1-7 *Dipetalonema dasyuri* 1, anterior end of female; 2, part of female, continuous with fig. 1 at AB; 3, lateral view of female, cloacal region; 4, posterior end of female, ventral; 5, spicules, ventral; 6, head of male, ventral; 7, spicules. Figs. 3, 5 and 7 are drawn to same magnification; 4 and 6 to scale beside 4

Explanation of Figures

References to Lettering—a, anus; ca, caudal ala; g, gland; i, intestine; l, larvae; o, ovary; oes, oesophagus; od, oviduct; ut, uterus; v, vagina; vu, vulva; vd, vas deferens; wut, wall of uterus.

D. capilliforme in having the oesophagus longer and differentiated into two parts, two pairs of cephalic papillae, the nerve ring further back, tail shorter, spicules relatively of different sizes, the vagina bending forwards and the vulva situated further back. It differs from *Dipetalonema dendrolagi* in the shorter length, relative lengths of two spicules, and the arrangement of the papillae in the cloacal region.

DIPETALONEMA ROEMERI (Linstow)

Figs. 8-13

Specimens have been examined from *Macropus major* (knee joint), *M. robustus* (knee joint and in body cavity), *M. melanops, M. dorsalis* (knee joint), *M. parryi, M. ruficollis* (tail muscles) and in *Onychogale frenata.*

These agree with Linstow's description, but in view of the large number of specimens examined, his account can now be amplified. As Baylis (1925) has noted, the larger spicule consists of a cylindrical proximal portion and a needle-like distal portion with which is associated inrolled alae. The number of cloacal papillae has been found to be subject to variation, there being usually four pairs of pre-anal, but we have found some with three pairs, others with four on one side and six on the other. There have always been found one pair of adanal, one pair immediately post-anal, and five pairs of lateral papillae, as well as a pair of small papillae near the mid-line behind these.

In the male there are eight papillae around the mouth, arranged in pairs laterally, dorsally and ventrally as in the diagram, and in the female four single papillae in these positions.

In the female the position of the ovarian tubes and oviducts varies with the age of the specimen, appearing in the older ones in the anterior region, even in front of the vulva. The oviducts pass back leading to the uteri which travel to the posterior end of the body, and return, joining near the end of the oesophagus. The vagina which begins soon after this junction, twists about before entering the vulva. The position of this varies with the age, the ratio of the total body length to the distance between the vulva and anterior end varying from 30:1 to 50:1. Females with this difference have been found either together or with the characteristic male of *D. roemeri*, and their general anatomy and dimensions such as the relation of length to thickness, the anterior end, the nerve cord and tail, are similar. The vulva, moreover, in almost all cases bears the same relation to the oesophagus, extending forward from the posterior end for one-half to one-quarter the length of the latter organ.

D. roemeri was described originally by Linstow (1905, 356-8) from material collected from the subcutaneous tissue of *Macropus antilopinus* Gould. No locality, except Australia, was given. The range of this species is the Northern Territory. Linstow quoted some references to *Filaria websteri,* but remarked that no description of it had been published.

In the catalogue of the Royal College of Surgeons, London (1830-37), there is reference to the *Filaria macropi majoris,* worms found in the capsular ligaments of the knee joint of a kangaroo. Diesing in 1851 altered the name to *F. macropodis gigantei.* Cobbold (1879, 433) renamed it *F. websteri* after its discoverer and mentioned that Bancroft had also found it in the great kangaroo. The latter sent much parasitic material to Cobbold from Queensland, and no doubt this record relates to material from that State. Bennett, in his "Wanderings in New South Wales" (1, 1834, 293), reported finding long thin white filariae encysted in the knee joint of *M. major* in New South Wales. Fletcher (P.L.S., N.S.W., **8**, 1883, 388) found *F. websteri* in the same species, also from New South Wales.

Other authors *(e.g.,* Molin, Linstow) have referred to some of the foregoing occurrences. Railliet and Henry in 1910 (C.R. Soc. Biol., **68**, 1910, 251) suggested that the species might belong to *Onchocerca.* Yorke and Maplestone (1926, 395) placed it under *Dirofilaria.* T. L. Bancroft (Trans. Inter. Med. Congr. Austr., 1889, 50; Austr. Med. Gaz., **12**, 1893, 258) also referred to the parasite from kangaroos, undoubtedly Queensland occurrences. Crisp (P.Z.S., 1853, **68**) mentioned the presence of *Filaria* sp. in the knee joint of a kangaroo. Johnston and M. J. Bancroft (P.R.S. Queensland, **32**, 1920, 45) referred to its occurrence in the knee joint of *Macropus parryi* and *M. giganteus* in the Burnett River district, embryos having been taken from the blood of the former.

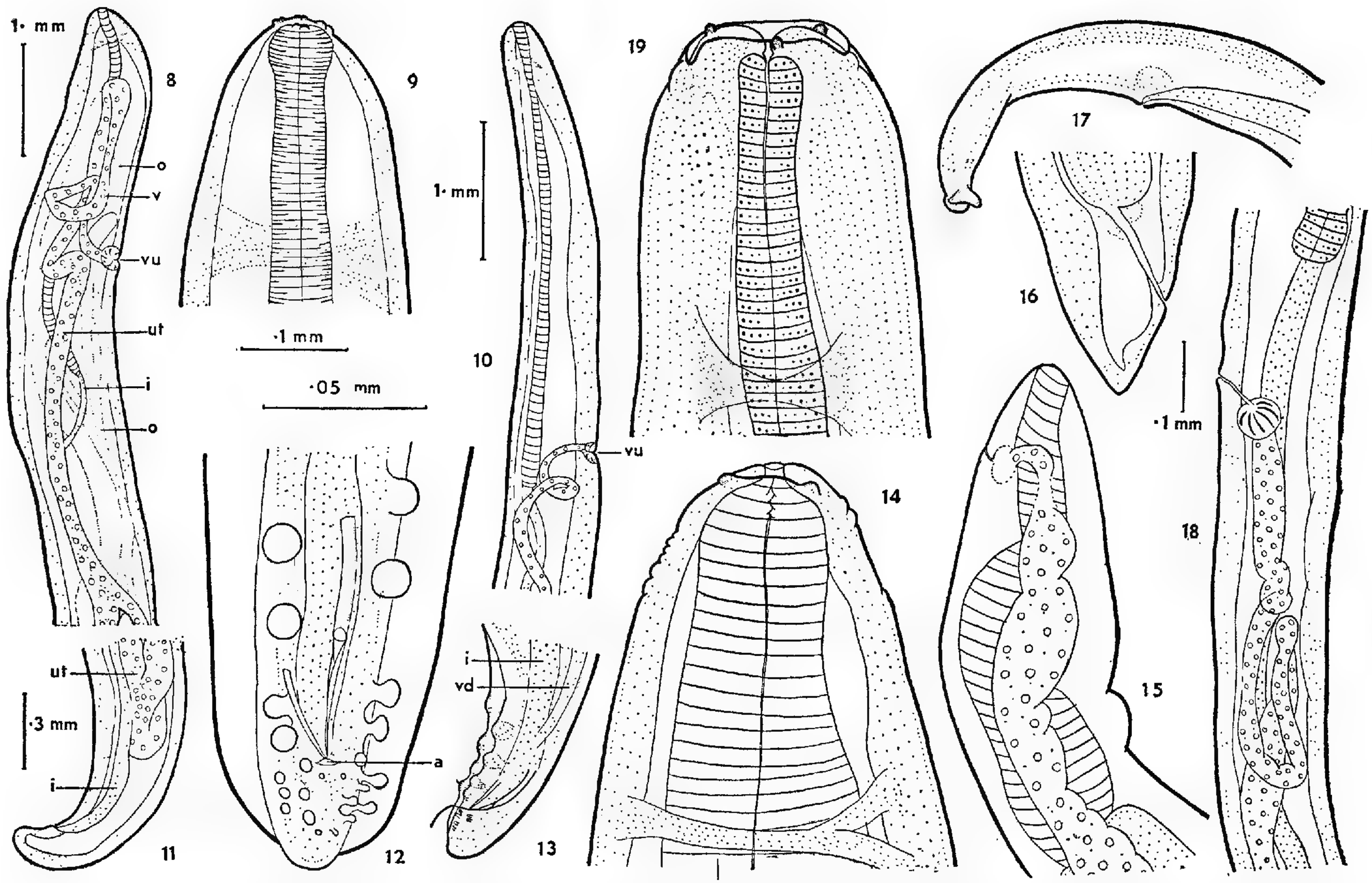
In spite of the numerous references to the parasite, no information regarding it has ever been published, apart from its location in certain species of kangaroos. Its specific name is consequently a nomen nudum. *D. roemeri* is undoubtedly the same parasite, as our experience has shown that it commonly frequents the knee joint of many species of *Macropus,* including the type host for *F. websteri.* Accordingly, we consider that the valid name should be *D. roemeri* (Linstow) instead of *Dipet. websteri* (Cobbold), which has no nomenclatorial standing.

Dipetalonema sp. (? D. roemeri)

Specimens from the coelome of a tree kangaroo, *Dendrolagus lumholtzii,* are all immature females. They are from 6·3 to 9·5 cms. long and 1·38 to 1·69 mm. in maximum diameter. The rounded anterior and posterior ends taper a little, the head being about 0·107 mm. broad and the width in the region of the anus 0·15 to ·2 mm. The distance from the anterior end to the nerve ring is about 0·42 mm.

The head has no lips or teeth and only two pairs of small lateral papillae. The walls of the most anterior portion of the oesophageal tube are slightly chitinised. The wide oesophagus is 2·7 to 3·1 mm. long, but is not straight. The intestine is wider, and can be seen by the naked eye as a brown-green line passing down almost to the anus. It narrows suddenly about 0·2 mm. from the anus, with which it is connected by a narrow tube. The tail is very short, 0·13 to ·21 mm. long, and bluntly conical.

There is in these young specimens no sign of ovarian tubes, but the uterus and the vagina can be distinguished in the anterior part of the body. The vulva is 0·54 to ·6 mm. from the anterior extremity.



Figs. 8-19

Figs. 8-13 *Dipetalonema roemeri* 8, anterior end of older female; 9, anterior end of male; 10, anterior end of young female; 11, posterior end of female, lateral view; 12, posterior end of male, ventral; 13, posterior end of male, lateral view, longer spicule extruded

Figs. 14-16 *Dipetalonema* sp. from *Dendrolagus lumholzii* 14-15, anterior end; 16, posterior end

Figs. 17-19 *Dipetalonema rarum* 17, female, posterior end, lateral view; 18, region of vulva; 19, female, anterior end

Figs. 9, 13, 14 and 17; 11 and 15; 12 and 19; 16 and 18 to same magnification

This must be regarded as an immature form, but its general anatomy, length and thickness agree most closely with those of *D. roemeri.* The oesophagus is, however, wider and somewhat sinuous.

Lumholz in 1884 (P.Z.S., 1884, 409) referred to the presence of parasitic worms in the subcutaneous tissues of this tree kangaroo, which he discovered in Northern Coastal Queensland.

Dipetalonema rarum n. sp.

Figs. 17-19

Specimens from *Onychogale frenata* comprised one whole female, the posterior end of another, and the anterior end of a male. They were taken from small subcutaneous nodules.

The worms are relatively thin and elongated, the female being 51·5 mm. long and 0·187 mm. maximum diameter. The head is rounded, bearing four lips and four small papillae; it is 0·126 mm. wide in the female and 0·059 mm. in the male. The tail is tapering, ending in a rounded point, and bears two rather large subterminal papillae. Across the anus the body width is, in the female, 0·09 mm. The tail is 0·27 mm. long. The oesophagus is 3·15 mm. long in the female and 2·7 mm. in the male. From the anterior extremity to the nerve ring is 0·252 mm. in the male, and 0·12 mm. in the female.

The testis tube starts with a bulb-like portion near the posterior end of the oesophagus and continues to a coiled part about the middle of the body, where it enters the vesicula seminalis; the rest of the body is missing just beyond this level.

The ovarian tubes extend almost to the anus; the two uteri unite a little behind the vulva, one of them being much bent just before this junction. The vagina is slightly coiled, then straight for a short distance before ending in a muscular bulb from which a narrow tube leads to the exterior. The vulva is just behind the posterior end of the oesophagus, being 3·55 mm. from the anterior end.

There is some difficulty in classifying this worm as the posterior end of the male is absent; the head, and the posterior end of the female, indicate the genus. *Dipetalonema;* the papillae of the head and the position of the vulva do not agree with any species so far described.

Plimmer (1912a, 407; 1912b, 137) referred to finding microfilariae in the blood of *Onychogale frenata* in the London Zoological Gardens, but originally from New South Wales. The adult worms occurred in the body cavity of the mother and of the foetus within the pouch. The species may, perhaps, have been *D. spelaea.*

Dipetalonema spelaea (Leidy)

Figs. 20-24

Leidy, in 1875, gave an account of this species from a "whallabee" as *Filaria spelaea.* Linstow (1897) described a parasite from a rock wallaby *(Petrogale)* as *Filaria australis.* Breinl (1911) described a worm from the body cavity of *Trichosurus vulpecula* as *F. trichosuri.* Leiper (P.Z.S., 1919, 620) recorded *F. australis* from a wallaby in London Zoological Gardens. Walton (1927, 111-113) re-examined Leidy's material and found it to belong to the same species as Linstow's, hence Leidy's name should stand. Baylis (1925) described a filariid from the common opossum, *Trichosurus vulpecula,* which resembled *F. australis* Linstow (or *F. spelaea),* except that the major spicule was much shorter and there was a difference in the anal and the caudal papillae, but decided that his material belonged to Linstow's species which he placed in *Acanthocheilonema.* Boulenger (1928) stated that he had examined specimens from *Halmaturus* sp. (i.e., a wallaby) which agreed very closely with Linstow's, but not with Baylis's description. He concluded that Baylis was dealing with a form closely allied to, but distinct from, Linstow's species. Oldham (1933, 30) listed the parasite as *Setaria spelaea,* as also did Railliet and Henry (1911). Thwaite (1927, 465) republished Leidy's account.

In 1934 Baylis published a list of synonyms of *Dipetalonema spelaea* (Leidy), including *F. australis* Linstow, *F. trichosuri* Breinl, 1913, and *Acanthocheilonema australe* Baylis, 1925. He stated that the most important difference lay in the length of the major spicule, and he assumed that this feature was variable within the species.

We have examined numerous worms from *Trichosurus vulpecula* and from *Petrogale penicillata,* and find that in males from the latter host the major spicule is always long, agreeing with Linstow's account, but that in those from *Trichosurus* it is short, agreeing with Breinl's description. The difference in size, moreover, is so great that we are unable to agree with Baylis in his identification, and we agree with Boulenger that there are two closely allied species

(1) *Dipetalonema spelaea* (Leidy); found in the body cavity of *Petrogale penicillata.* Synonyms: *Filaria spelaea* Leidy, 1875; *F. australis* Linstow, 1897; *Setaria spelaea* Railliet and Henry, 1911; *Acanthocheilonema spelaea* Walton, 1927; *Dipetalonema australe* Boulenger, 1928.

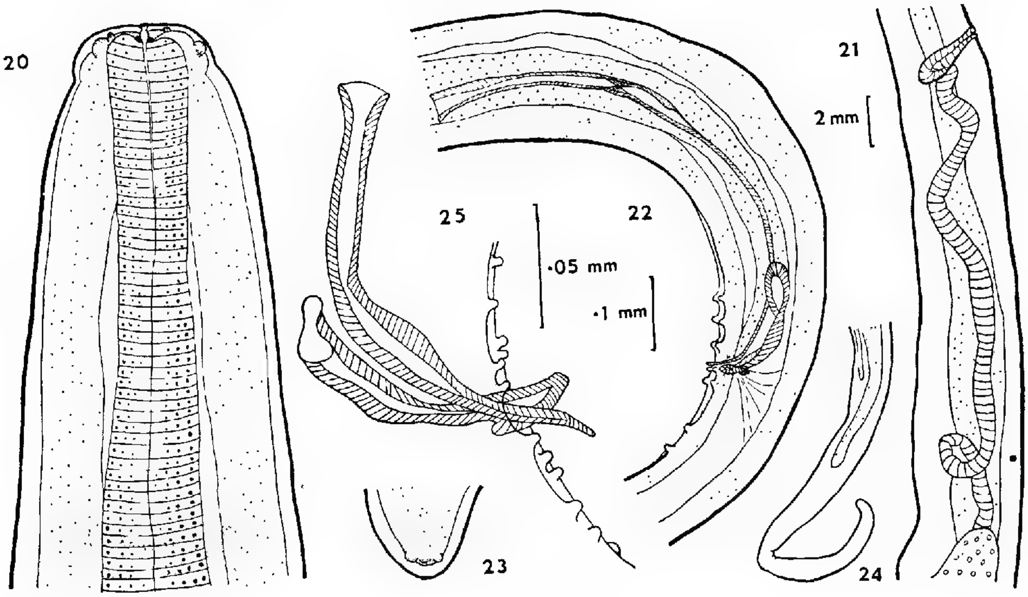
(2) *Dipetalonema trichosuri* (Breinl); found in the body cavity of *Trichosurus vulpecula.* Synonyms: *Filaria trichosuri* Breinl, 1913; *Acanthocheilonema australe* Baylis, 1925; *Breinlia trichosuri* Yorke and Maplestone, 1926.

We have also found males corresponding to Linstow's and to Boulenger's description from the subcutaneous tissues of *Dendrolagus benettianus,* a tree kangaroo from North Queensland.

Parasites belonging to *Dipetalonema spelaea* are long thin worms with rounded anterior end and tapering tail. The cuticle is marked with definite transverse striations which are close together. The male is about 11 to 12 cms. long, with maximum diameter of 0·32 mm.; the female is 23 to 24 cms. long with a maximum diameter of 0·66 mm. There are two large and four small papillae on the anterior end; the mouth leads to a short vestibule surrounded by a chitinous ring. The oesophagus is not divided into two parts; in the male it is 1·9 mm.

and in the female 1·55 mm. long. The nerve ring is about 0·246 mm. from the anterior end in the male, and 0·28 mm. in the female. The intestine is rather narrower than the oesophagus and is straight. The tail is long, 1·3 mm. in the female, 0·86 mm. in the male.

The spicules are unequal, the longer, 1·01 mm., is cylindrical proximally, and then flattened out, the distal half of its length being needle-like, curved and tapering. The smaller is about a quarter of its length, *i.e.*, 0·25 mm., and has a massive proximal part and a spatulate distal part rolled at the edges. There is



Figs. 20-25

Figs. 20 24 *Dipetalonema spelaea* 20, male, anterior end; 21, vulva; 22, male, cloacal region; 23, tip of male tail; 24, female tail

Fig. 25 *Dipetalonema trichosuri* Cloacal region Figs. 20, 23 and 25; 21 and 24 to same scale

an accessory piece projecting back from the distal end. Only three pairs of pre-anal and three pairs of post-anal papillae were distinguished. The tail is in a spiral of two or three turns.

The vulva is 5·1 mm. from the anterior end, and is associated with a pyriform muscular bulb from which the vagina leads back, more or less coiled according to the age of the specimen, to the uterus which divides into the two branches after a short distance (1·7 mm.). It is opisthodelphous. The ovarian tubes do not extend to the anal region.

This species is somewhat like *Filaria trichosuri* but is distinguished from it by the length of the major spicule and the position of the vulva, which in Breinl's specimens is further forward.

It differs from *F. dentifera* Linstow in the absence of a dorsal head-papilla, relative sizes of the spicules, and the position of the vagina.

In general anatomy and measurements the present specimens are to be identified with Linstow's *F. australis,* although only three pre-anal and three post-anal papillae have been detected. The female of *F. spelaea,* as described by Walton 1927, agrees with *F. australis,* so Leidy's specific name should, as Walton points out, take precedence. As the specific name is the plural of a Latin substantive and not an adjective, we have not altered it to agree with the genus.

Eisig (Z. f. wiss. Zool., **20,** 1870, 99-102) gave an account of *Filaria* sp. from the pericardium of *Halmaturus bennetti* in the Heidelberg Zoological Gardens. Only females, 90-100 mm. in length, were present. There were stated to be two rows of papillae, each with six, at the head end, and the oesophagus was reported to be one-fortieth of the total length. One of us has pointed out (Johnston, 1909, 518) that the host is a Tasmanian wallaby, *Macropus ruficollis* var. *bennettii.* The arrangement and number of the head papillae prevent us from assigning the species to any of the filariids described from Australian marsupials. *D. roemeri* and *D. tenue* seem to be nearest.

Dipetalonema trichosuri (Breinl)

Fig. 25

We have examined many specimens of this species from the common opossum, *Trichosurus vulpecula,* from Queensland, including a female from Breinl's type material, and find them to agree with Breinl's *F. trichosuri* in every way except that there appears to be only one pair of subterminal papillae and the tail ends in a small median papilla. It is to be distinguished from *D. spelaea* by the position of the vulva and the relative lengths of the spicules; and from *F. dentifera* by the absence of dorsal head-papilla, in the shape of the spicules, and in the number of cloacal papillae. The spicules of this species are shown in fig. 25.

Yorke and Maplestone (1926, 400) published figures (fig. 273) and made the species the type of a new genus *Breinlia,* but Baylis (1934, 551) and subsequent workers regard the latter as a synonym of *Dipetalonema.*

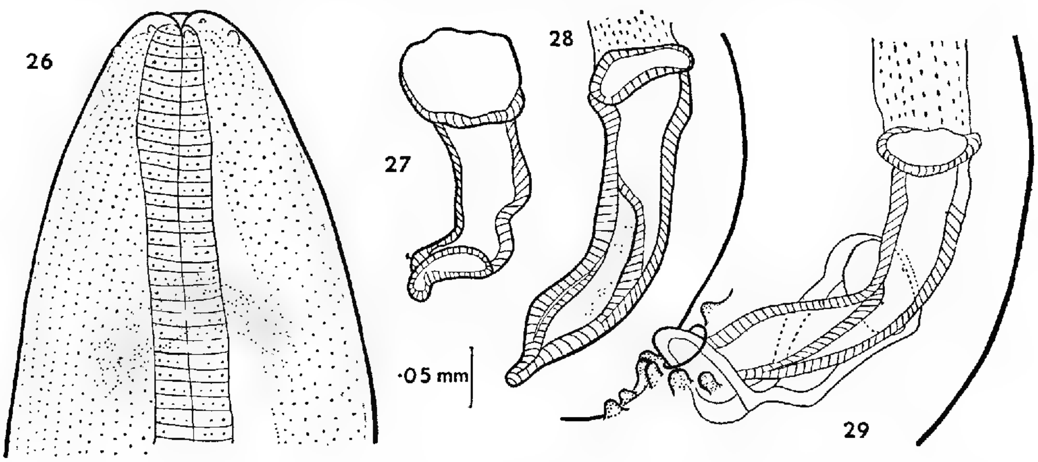
Scott (P.Z.S., 1926, 237) reported finding filarial larvae in an opossum, *Pseudochirus lemuroides,* in the London Zoological Gardens. The habitat of the host is north-eastern Central Queensland. Linstow (1898, 460) described *Filaria dentifera* from the body cavity of *Phalangista (= Trichosurus) vulpecula,* collected by Semon in Queensland—probably in the Burnett River district. Stiles and Hassall (Index Cat. Med. Vet. Lit. Roundworms, 1920, 466) have, in error, quoted the host as *Trichiurus vulpecula.* The parasite has not been satisfactorily placed generically.

Dipetalonema annulipapillatum n. sp.

Figs. 26-29

Only males of this species were found; specimens being obtained from the knee joint of *Macropus dorsalis,* the coelome of *M. ualabatus* and the subcutaneous tissue of *Onychogale frenata.*

It is a long thin worm, 5 to 7 cms. long, and with a maximum breadth of 0·2 to 0·3 mm.; the tail is coiled in a tight spiral of four to six turns; the anterior and posterior ends are rounded, the anterior having two lateral epaulette-like structures, and the posterior with a median terminal and two subterminal papillae. The tail is about 1·1 mm. long. The papillae on the anterior end are difficult to distinguish, but there appear to be two large laterals and four smaller ones around the mouth. The nerve ring is about 0·25 to ·27 mm. from the anterior end. The mouth is situated in a depression at the anterior end; the oesophagus is 1·6 to 2 mm. long, and the intestine, starting with a slight bulge, is narrower.



Figs. 26-29

Figs. 26-29 *Dipetalonema annulipapillatum* 26, male, anterior end; 27, shorter spicule; 28, longer spicule; 29, cloacal region. All figs. to same scale

The testis tubule begins just posterior to the commencement of the intestine. The vas deferens can be traced to the beginning of the cylindrical proximal end of the larger spicule. The latter is about 0·4 mm. long, and the distal part is spatulate with rolled edges, and ends in a blunt point. The shorter spicule is 0·3 mm. long and is broad and spatulate, forming a groove for the longer. The cloacal region is somewhat elevated and with it are associated several papillae arranged in a ring, consisting of three pairs of peri-anal, one pair of post-anal, and one pair of pre-anal. This is a different arrangement from that in any species of *Dipetalonema* described hitherto.

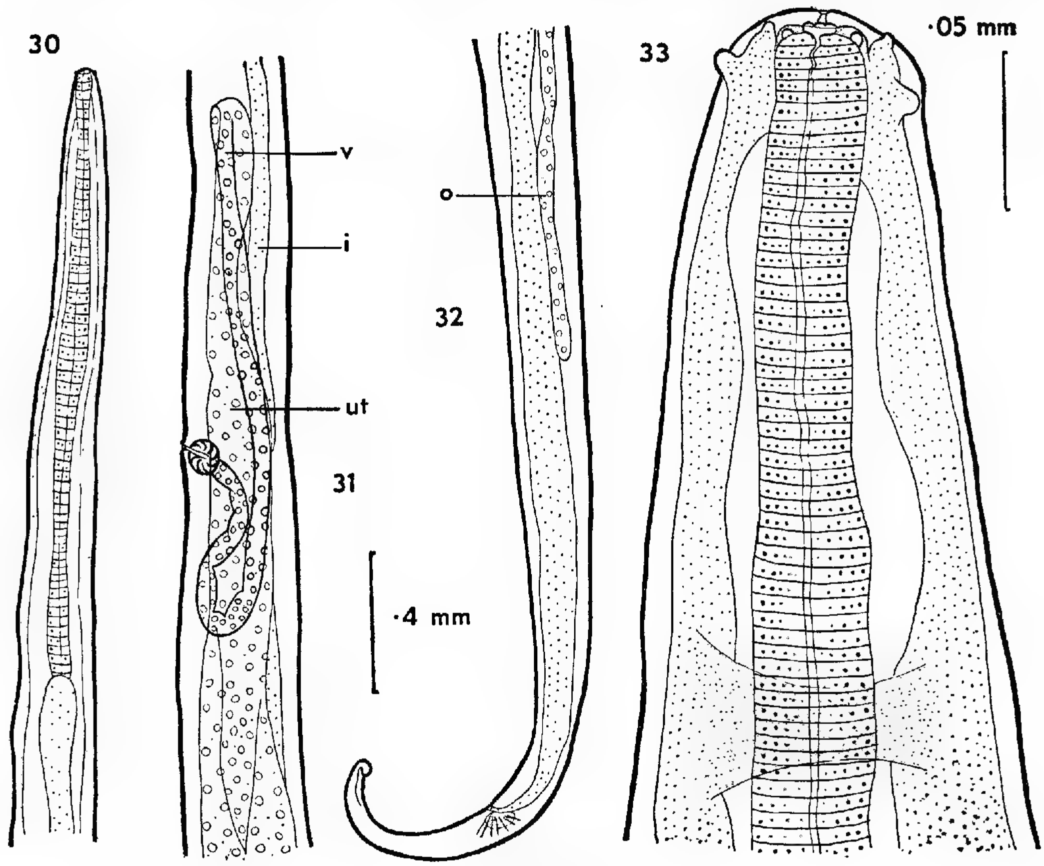
Dipetalonema tenue n. sp.

Figs. 30-33

Some female filarial worms not agreeing with any previously described species were found among the viscera of two specimens of the euro, *Macropus robustus*. They are exceedingly long and thin, 20 to 30 cm. long and 0·59 to ·65 mm. wide. The head is rounded, bears one pair of large lateral and four (?) smaller papillae, and is 0·086 to ·069 mm. wide. The nerve cord is about 0·27 mm.

from the anterior end. The oesophagus is simple, 2 to 2·9 mm. long, and is followed by a straight intestine of about the same width, though the part immediately following the oesophagus may be somewhat dilated. The anus is 0·75 to 1·25 mm. from the posterior end. The tail tapers and is curved, the end being bluntly pointed; there are two very small subterminal papillae.

The ovarian tubes do not extend to the anal region. The two uteri pass forward to the region of the vulva, where they are united into a single uterus



Figs. 30-33

Figs. 30-33 *Dipetalonema tenue* 30, female, anterior end; 31, region of vulva; 32, female, posterior end; 33, female, anterior end. Figs. 30-32 to same scale

which passes forward almost to the beginning of the intestine and then enters the vagina which leads back to the vulva. The distance from the anterior end to the vulva is one twenty-seventh to one thirty-fourth of the total body length.

The larvae are not enclosed in shells; as they grow older they elongate and uncurl in the uteri. The younger are 0·07 by ·01 mm., the older 0·246 by ·225 mm.

This worm differs from *D. spelaea* and *D. trichosuri* in the position of the vulva, which is much further back, and in the position of the nerve ring.

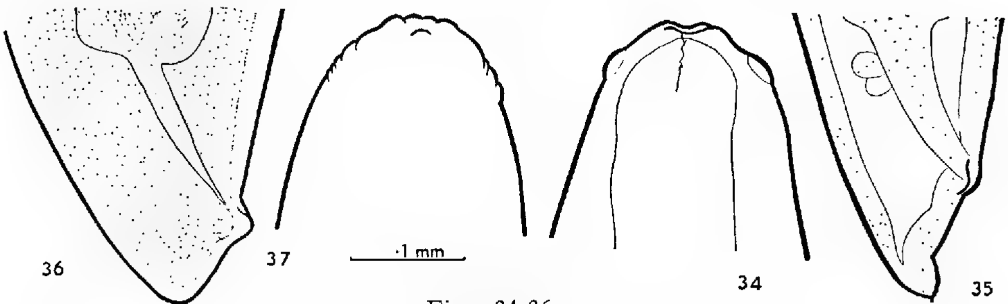
It differs from *Filaria dentifera* in the absence of a dorsal head-papilla; from *D. capilliforme* in the position of the vulva which is much further back, and in the arrangement of the papillae on the head (*D. capilliforme* does not appear to have the two large lateral papillae); and from *D. dendrolagi* Solomon in the length of the body and the size of the larvae.

FILARIA (s.l.) spp.

The following specimens have not been fully examined because they could not be cleared sufficiently:

(1) A female from the coelome of a "native cat," *Dasyurus maculatus*, short and thick, 65 mm. by 0·963 mm. The head is rounded, 0·154 mm. wide, and has four peri-oral and two large and low lateral papillae. The intestine narrows a short distance before the anus. The tail is short and bluntly pointed, 0·154 mm. long, and ends in a narrower part like a huge papilla (figs. 34-35).

(2) From the peritoneum of *Trichosurus caninus:* two worms were found which, judged by the absence of specialization in the anal region, are females. They are about 7 cm. long, 0·88 mm. in thickness. There are four to six peri-oral papillae. The head is 0·15 mm. across (fig. 36). The tail is short, in one specimen ending in an elongated portion, like the one described above. The anus lies between two papillae, 0·099 mm. from the tip of the tail (figs. 36-37).



Figs. 34-36

Figs. 34-35 *Filaria* (s.l.) sp. from *Dasyurus maculatus*
Figs. 36-37 *Filaria* (s.l.) sp. from *Trichosurus caninus*

(3) From the liver of *Potorous tridactylus:* a single worm was found, 7 cm. long and 1·5 mm. wide—though the width may be less as the worm was split. The head is rounded, 0·12 mm. across, and followed by a constriction 0·09 mm. from the anterior end. The tail is bluntly pointed. No peri-oral papillae can be seen, nor can any details of the anatomy be distinguished.

We record the occurrence of *Dipetalonema* sp. in the knee joint or in the coelome of the rock wallaby (*Petrogale xanthopus* Gray), euro (*Macropus robustus* Gould), and kangaroo (*Macropus major* Shaw) of the northern Flinders Ranges and adjacent regions in South Australia, but, unfortunately, specimens are not now available to determine whether they belong to *D. roemeri* or *D. spelaea*, or to both.

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ABORIGINAL MESSAGE STICKS FROM THE NULLABOR PLAINS

BY C. P. MOUNTFORD

Summary

This brief paper places on record the description of six message sticks, five from the Nullabor Plains and one from Eucla. The significance of three out of the six sticks, *i.e.,* figures 1, 6, and 7, is also given.

I am indebted to Mr. Allen Musgrave for having, at my request, collected from the natives of the Nullabor Plains the sticks shown in figures 1, 5, 6 and 7, and having obtained the meanings of the above-mentioned three; also to Mrs. J. White, and Miss A. Lock for the loan of those shown in figures 10 and 3 respectively.

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By C. P. Mountford, Acting Ethnologist, South Australian Museum

[Read 9 June 1938]

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Description

Figure 1 pictures a message stick, which was a communication from the Karonie to the Ooldea tribe. The following is the meaning obtained from the possessor of the stick.

Column 1 (fig. 2) The small dots are the "spinifex" natives[1] who are travelling towards, and expected at Cook before many days. The concentric circles, H, J, K, and L indicate the water-holes on which the travelling party will depend. H is called Mulgeru; J, Nilida; K, Mulunga; and L, Wadiga.

Column 2 A group of natives who are camping at Tarcoola.

Column 3 The aborigines at Ooldea.

Column 4 A second party of "spinifex" natives, who are expected to arrive at Cook in advance of those indicated in Column 1. M, N, O, P probably refer to water-holes, although this was not specified.

It is interesting to notice that only those natives who are obliged to travel over the practically waterless desert of the Nullabor are associated on the message sticks with the water-hole symbols.

Column 5 A small party of both sexes who have already arrived and are temporarily camping at Cook.

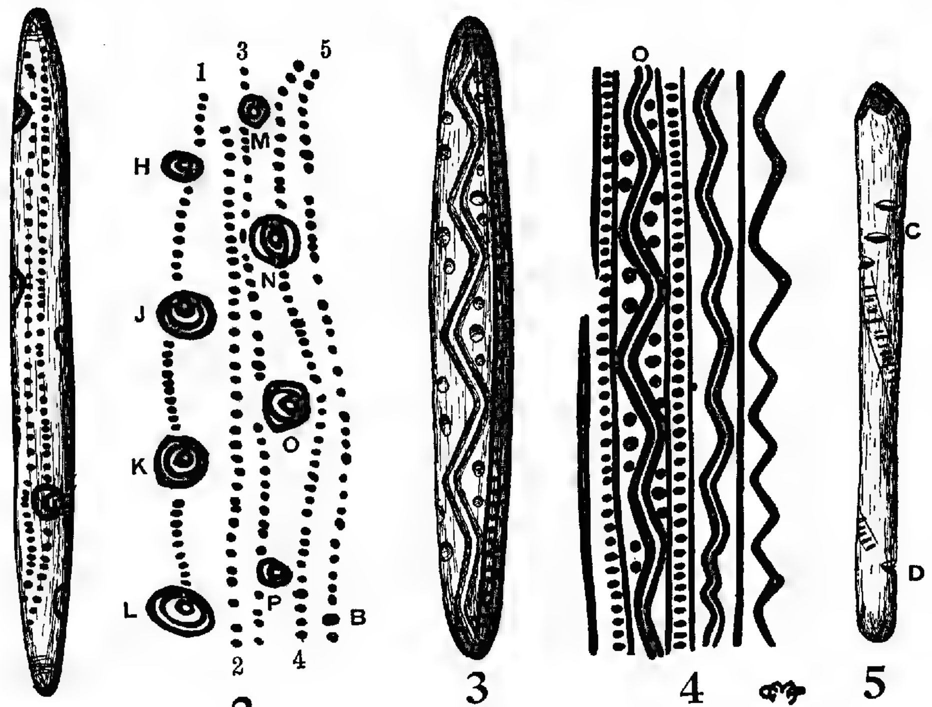
The stick was 21 cm. in length and 2 cm. major diameter. It was circular in section, tapering down to a blunt point at either end. When received it was wrapped in a fragment of old clothing, and bound with European string. The pattern had been incised with an engraving tool about .2 mm. in width.[2]

(1) Aborigines who live in the inhospitable and unexplored northern part of the Nullabor Plains.

(2) The natives, unaffected by European contact, used the front incisor tooth of the opossum, still in place in the skull of the animal, as an engraving tool. This is used in a similar manner to that employed by a European craftsman, except that the aborigine, not having a handle on his tool, that can be rested against the palm, has to exert the necessary engraving force with his finger tips. The writer has observed an aborigine of the Ngada tribe of the Warburton Ranges of Western Australia, whilst he was engraving a design on the back of a spear-thrower, and the regularity of the design and the skill displayed in the handling of the small awkwardly-shaped engraving tool was remarkable.

Figure 3 was collected by Miss Lock while in charge of the Ooldea Mission Station. The engraved design, the meaning of which was, unfortunately, not obtained, is shown in figure 4. The stick was 20 cm. in length, somewhat cigar-shaped, with a major diameter of 21 mm. Mr. N. B. Tindale showed me an aboriginal drawing from the above locality which was almost identical with O, figure 4. The meandering line in this case represented the ancestral snake, *Kanba*, and the dots, placed symmetrically on either side, the eggs of that reptile.

The message stick depicted in figure 5, had been engraved with a spiral pattern of transverse marks which started at the three cuts at C, and terminated at the two cuts at O, X. When received, the design was completely obscured by



1 2 3 4 5

a wrapping of woollen thread of European manufacture. This example was 11 cm. in length, 6 mm. maximum diameter and had been cut and smoothed from a twig of circular section by means of a steel tool.

Figure 6 was obtained from a locality on the Trans-Australian Railway Line approximately on the border of South and Western Australia. Three tribal groups are indicated: one from Laverton, a town some 200 miles north, one belonging to the Muramul tribe, and the other, the people whose territory is adjacent to the Karonie Mission Station, which is situated adjacent to the railway line and some 60 miles east of Kalgoorlie.

The meaning, as obtained from the sender of the stick, is as follows:—

B, figure 7, is the sender of the stick, and A the Karonie railway dam. (The use of the U-shaped symbol for a dam is noteworthy.) The line of dots, 1 E, represents the aborigines who reside permanently at the Mission Station; line D, the end of which terminates at one limb of A, those who "sit down along railway line," *i.e.*, camp beside the railway line. The group of natives from Laverton is indicated by the line C, while G refers to the Muramul tribe, which sometimes visit the Karonie Mission Station. M symbolizes the above Mission.

The stick (fig. 6) is circular in section, 25 cm. long, and 13 mm. major diameter, tapering to a blunt point at both ends. The lines of dots, which are arranged spirally, had been burnt in, probably by a heated piece of metal, although the glowing end of a small fire stick is used for a similar purpose by the tribalized natives who live to the north in the Mann and Petermann Ranges. When collected, the stick was carefully wrapped in a discarded piece of clothing and bound with string.

In figure 8 the cuts above F (fig. 9) are the aborigines at Ooldea. The long incision F is the Ooldea soak,[3] while those below this symbol indicate unspecified individuals, as do the marks above symbol G. The latter refers to the Mission Station at Ooldea, and the symbols below that point are a message to the recipient of the stick that the missionary at Ooldea only gives one meal a day, and that only of wheat porridge.

This stick is of circular section, and slightly curved, and is 25 cm. long and 17 mm. diameter. The cuts forming the pattern had been made with a steel knife.

Figure 10 originally belonged to an aborigine whose tribal country was adjacent to the now deserted Eucla telegraph station. The stick resembles those collected on the Trans-Australian railway line, and for that reason is included.

This specimen is somewhat longer than the other examples described and has a mass of spinifex gum attached to one end of the stick. The length is 25 cm., and the diameter 16 mm. The design consists of more or less parallel engraved lines, and rows of dots, which extend the whole length of the stick. A steel tool had been used to produce these marks.

Discussion

Message sticks are known over the greater part of Australia. Roth (1) figures fourteen message sticks obtained from the aborigines of north-western Queensland. The associated meanings were given for the majority of those figured.

Love (2) writes of the message sticks of the Worora tribe of North-West Australia. He mentions that the sticks are crudely made and appear to act more as passports than actual conveyors of messages.

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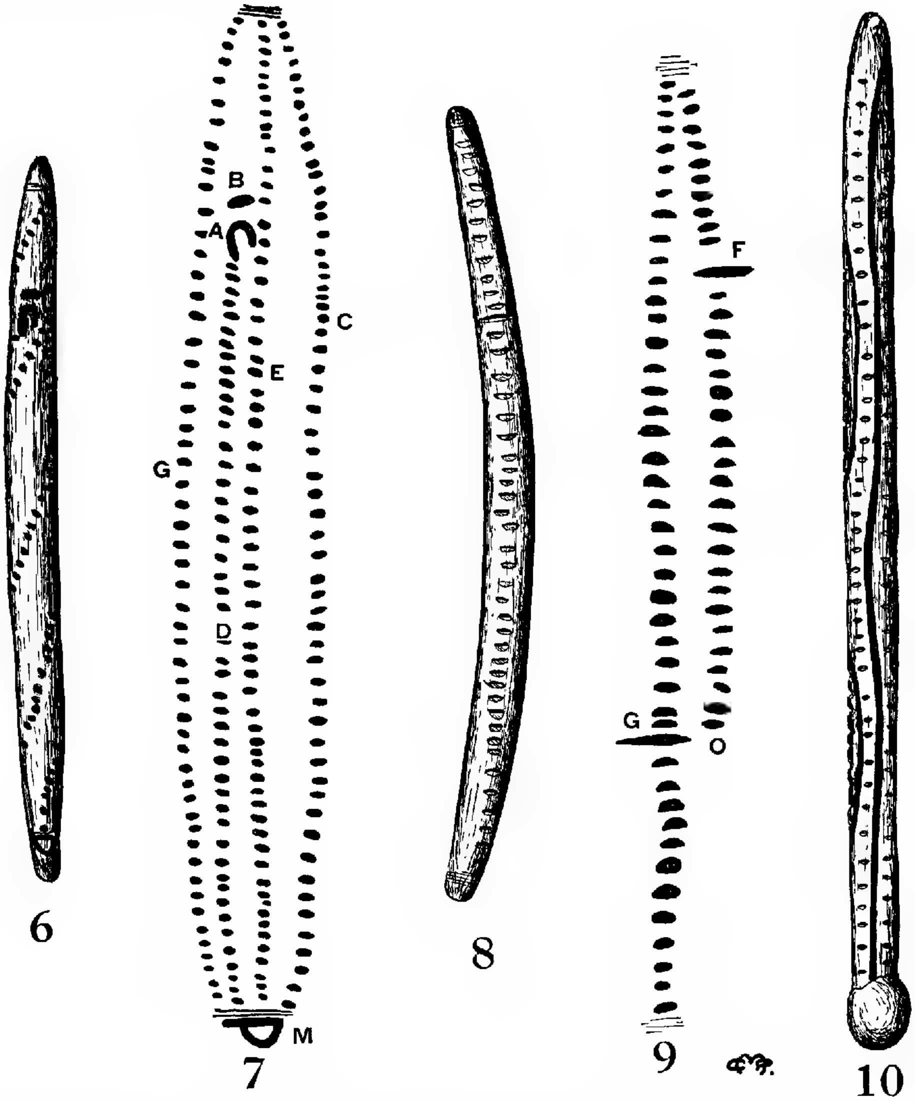
(3) The present camping place of the aborigines of this district. The name "soak" is an outback term for a water catchment filled with sand.

The writer has been shown carved message sticks by the aborigines of Melville Island which, according to the aborigine possessing them, figure the locality from which the stick originated, a request for provisions, and the mark of the sender himself.



Spencer and Gillen (3), however, claim that message sticks of the type described in this paper, and also by Roth and Love, are not used by the aborigines of Central Australia. The extent of the area in which message sticks are not used is unknown, but it seems likely that Spencer and Gillen's observation would only apply to the Central parts of the continent.

Although one often hears of cases where natives have received and deciphered message sticks, conveyed to them by Europeans who themselves were unaware of the significance of the symbols, the writer has been unable to locate any one such case, even after considerable correspondence. Roth describes in detail the methods in use in his area for the transmission of the message, and both Love and Roth agree that the engraved design is no more than some kind of mnemonic aid, or form of passport.

It is likely, however that certain standard designs are used for specific purposes, such as notifications or invitations for forthcoming ceremonials. The significance of such sticks, even when presented without a verbal message, would be apparent to the recipient.

Summary

This paper places on record the details of six aboriginal message sticks, five from the Nullabor Plain, adjacent to the Trans-Australian railway line, and one from Eucla.

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(2) Love, J. R. B. 1936 "Stone Age Men of Today," 189

(3) Spencer and Gillen 1899 "Native Tribes of Central Australia," 142

LARVAL TREMATODES FROM AUSTRALIAN TERRESTRIAL AND FRESHWATER MOLLUSCS
PART IV CERCARIA (FURCOCERCARIA) MURRAYENSIS N.SP.

BY T. HARVEY JOHNSTON AND E. R. CLELAND

Summary

Cercaria murrayensis was one of the commonest larval trematodes present in Limnaea lesson; gathered from the River Murray near Tailem Bend. In May, 1937, fourteen of 119 specimens gave off these cercariae in the aquarium; in June only five of these snails, all uninfected, were obtained; in early December eight out of 135 were found infected ; in March, 1938, eight out of 41 ; and in April six out of 48. In early December, during an excursion to Swan Reach, River Murray, under the auspices of the newly-formed Tate Society, we collected 439 specimens of the Limnaea, 200 of which gave off these cercariae in the aquarium.

LARVAL TREMATODES FROM AUSTRALIAN TERRESTRIAL AND FRESHWATER MOLLUSCS

PART IV CERCARIA (FURCOCERCARIA) MURRAYENSIS n. sp.

By T. Harvey Johnston M.A., D.Sc., and E. R. Cleland, M.Sc.,
University of Adelaide

[Read 9 June 1938]

Cercaria murrayensis was one of the commonest larval trematodes present in *Limnaea lessoni* gathered from the River Murray near Tailem Bend. In May, 1937, fourteen of 119 specimens gave off these cercariae in the aquarium; in June only five of these snails, all uninfected, were obtained; in early December eight out of 135 were found infected; in March, 1938, eight out of 41; and in April six out of 48. In early December, during an excursion to Swan Reach, River Murray, under the auspices of the newly-formed Tate Society, we collected 439 specimens of the *Limnaea,* 200 of which gave off these cercariae in the aquarium.

The parasites could be recognised easily when the tube containing them was held against the light, the greater number maintaining a characteristic resting position (fig. A), suspended in the water. In this the tail stem was usually perpendicular and the two furcae were separated by an angle of about 120°. The proximal part of the tail stem was bent and in line with the body, making a considerable angle with the rest of the tail. By far the greater number of cercariae were motionless at any one time, and the resting period usually varied between five and thirty seconds. This inactivity was broken by short bursts of movement, and the cercaria would move rapidly tail foremost (fig. B) twisting itself spirally and varying the rate of speed. As the greater number were hanging with the tail stem more or less perpendicular, the general movement was upwards, but could occur in any direction, the latter sometimes changing.

In measuring cercariae, the method outlined by Cort and Brackett (1937) was followed and the material killed by adding to it an equal volume of boiling 10% formalin. Specimens were examined and the following are the measurements of 30: length of body 138 μ - 185 μ, average 158 μ; breadth of body across ventral sucker 32-46 μ, average 37 μ; anterior tip of body to centre of ventral sucker 77-131 μ, average 100 μ; length of tail stem 161-208 μ, average 188 μ; width of tail stem 24-34 μ, average 27·5 μ; length of furcae 154-200 μ, average 173 μ; length of anterior organ 45-60 μ, average 54 μ; length of posterior sucker 22-29 μ, average 25·9 μ; breadth of posterior sucker 22-27·5 μ, average 25·7 μ.

The body was finely corrugated, and thus it was extremely difficult to see the body spines clearly. The large anterior organ showed no differentiation into two parts, and the well developed ventral sucker lay just behind the middle of

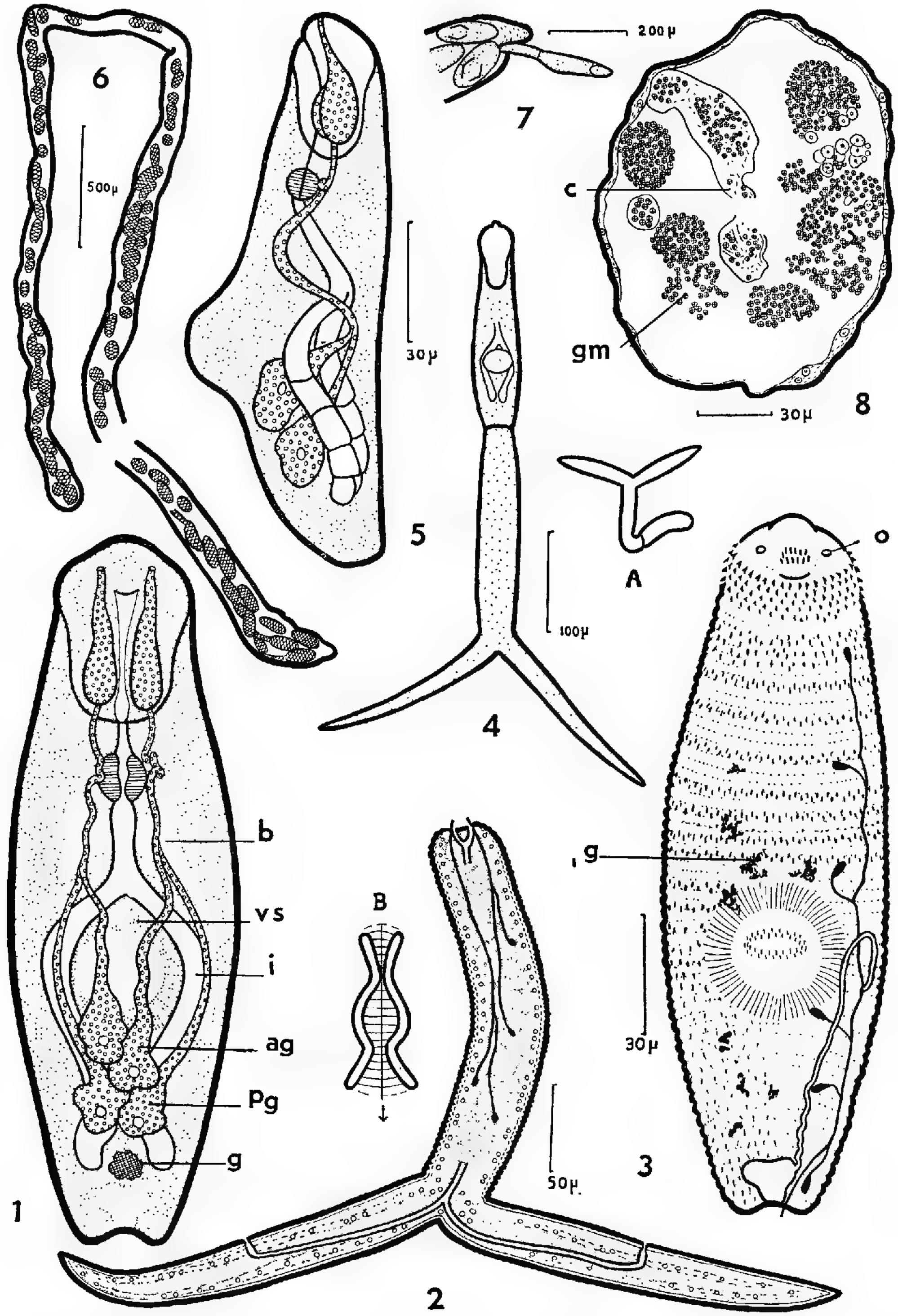


Fig. A, cercaria in resting position; B, cercaria moving; 1, body of cercaria; 3, tail; 3, excretory system, spination; 4, entire cercaria; 5, lateral view of cercaria; 6, portions of a sporocyst; 7, cercaria emerging from sporocyst; 8, T.S. sporocyst. Figs. 1, 3 drawn to same scale the body. Yellow pigment granules were present scattered throughout the body, and concentrated into two groups lying near the junction of the intestinal caeca.

About twelve large forwardly directed spines occurred on the highly contractile anterior tip in front of the mouth (fig. 3). Surrounding this region was a flattened spineless area on which opened the mouth and the ducts of the gland cells. This was succeeded by a collar of spines of varying sizes arranged somewhat irregularly in from five to seven rows, with the largest spines in front. Another spineless area separated these from the much smaller spines of the general body surface. These latter, larger on the ventral than on the dorsal surface, were arranged irregularly just below the collar, with a tendency to form rows on the ventral surface, and behind this they were grouped in nine double rows, the last being on a level with the middle of the ventral sucker. The spines posterior to this were arranged irregularly on the ventral surface, and were much more numerous at the posterior end near the tail. Two irregular rows were present on the ventral sucker. We were unable to ascertain whether there were any minute spines on the tail stem, but they appeared to be present on the furcae.

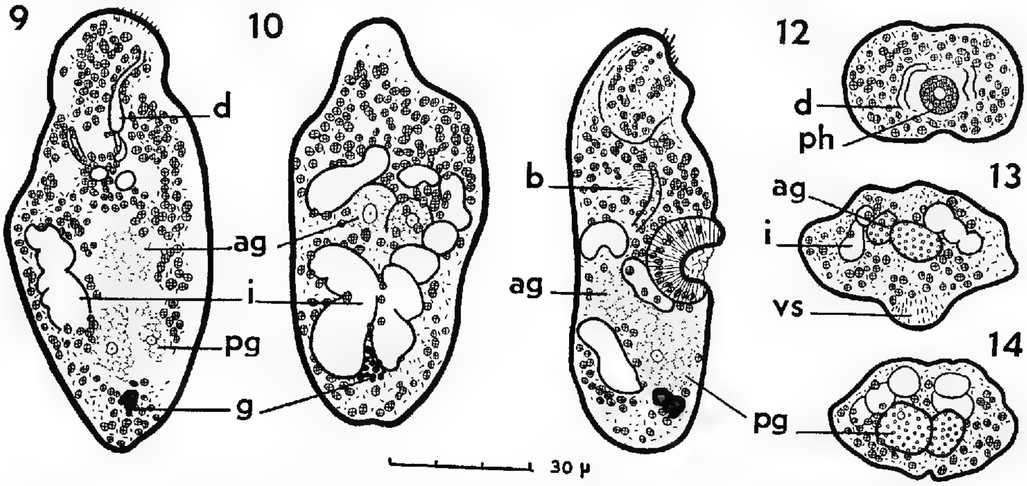
The mouth was subterminal, the pre-pharynx short and the pharynx well developed. The oesophagus bifurcated just in front of the ventral sucker into the well-defined caeca, which were characteristically bent and reached almost to the bladder. They were filled with a clear refracting substance which was not continuous but separated into masses, so that the intestine appeared at first sight to be composed of a few large cells. It stained well with neutral red.

The four gland cells (figs. 1, 5) stainable with nile blue sulphate lay behind the acetabulum, ventral to the caeca. They were coarsely granular and slightly lobed with large clear nuclei, and arranged in two pairs, those in the first pair being somewhat tandem, and those in the second opposite. The ducts passed forwards in two pairs, following the course indicated, and in all but fully extended specimens were twisted in the region of the pharynx. After entering the anterior organ they became much enlarged, then narrowed before opening dorso-laterally on the circumoral spineless area.

The genital primordium consisted of a mass of undifferentiated cells lying between the ends of the caeca and the bladder. The nervous system was represented by an H-shaped mass of tissue lying posterior to the pharynx. Longitudinal and circular muscle fibres were present in the tail stem, and there were about forty caudal bodies of varying size with a tendency to become arranged in indefinite groups.

From each of the antero-lateral borders of the small bladder, mushroom-shaped when fully distended, arose a main excretory duct. Each was slightly coiled and proceeded upwards and outwards to about the middle of acetabulum, where it doubled back and, on a level with the posterior margin of the ventral sucker, gave rise to an ascending and descending branch. The flame cell formula was $2 \times (6 + 2) = 16$. Of the three flame cells connected with the anterior tubule, one lay alongside the anterior organ, the second near the pharynx, and the third just in front of the acetabulum. Of the three connected with the descending branch, one was just posterior to the ventral sucker, the second about midway between this and the posterior end, and the third alongside the bladder. The descending tubules passed into the tail stem, each bearing two flame cells. The island of Cort was small, and the main excretory tube passed down the centre of the tail stem to divide into two just before reaching the furcae. Each branch opened on the edge of the furca (fig. 2) about half-way along its length.

The sporocysts present in tangled masses in the liver were very hard to separate. They were attenuated, one end being pointed with a birth pore just behind the tip, and the other end bluntly rounded. They contained numerous germ balls and developing cercariae. Older sporocysts had a thin wall formed of cuticle and sparse, flattened epithelial cells (fig. 8), the latter being several layers deep at the end of the sacs. Germ masses and mature germ cells were typical.



Figs. 9, 10, consecutive longitudinal horizontal sections of cercaria; 11, longitudinal section of cercaria; 12, 13, 14, Tr. sections through a cercaria

Cort and Brackett (1937a) gave a brief resumé of the Strigeid cercariae obtained from Douglas Lake, Michigan, and of these our specimen resembles most closely *C. flexicauda* and *C. yogena*. The behaviour in free life of our species was almost identical with that of the former (Cort and Brooks, 1928), and its average lengths of body, tail stem and furcae respectively were 158 μ, 188 μ, 173 μ, compared with 170 μ, 254 μ and 226 μ in *C. flexicauda*, and 173 μ, 236 μ and 221 μ in *C. yogena*. Our species was considerably smaller than both the American forms and the furcae and tail stem both approximated more nearly to the length of the body. The spination resembled most closely that of *C. yogena*, and the pigmentation characteristic of the American form was almost identical with ours, though as yet no pigmentation has been seen in the tail stem. The caudal bodies and excretory system resembled those of *C. flexicauda*, while differing from those of *C. yogena*. There was no ciliation of the main collecting tubes as in the latter and the position of the flame cells differed. The anterior organ was the same length as in *C. flexicauda,* but the ventral sucker was smaller, being 26 μ long in our form and 35 μ in the American.

Cort and Brackett (1937 b) published a paper on the identification of Strigeid cercariae, utilizing differences in their behaviour during free life. Before receiving their article we had already noticed such behaviour in our specimens, and were able to distinguish the species with the naked eye from amongst a collection of cercariae.

Wesenberg-Lund (1934) drew attention to that group of Strigeid cercariae characterised by the presence of four penetration gland cells behind the ventral sucker, which had been mentioned by Cort and Brooks (1928). To this *Proalaria* group of pharyngeal, longifurcate, distome cercariae of Miller (1926) our species belongs, and appears to us to be a typical member, having for its intermediate stage a *Diplostomulum* present in the eyes of certain freshwater fish.

We suggest the name *Cercaria murrayensis* for this *Proalaria* larva and propose to give an account of experimental infections of various fish in a later paper.

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EXPLANATION OF FIGURES

All drawings were made with the aid of the camera lucida, except figs. A and B, and the details of fig. 3. Figs. drawn to scale indicated.

Ag, anterior gland cell; b, brain; c, cercaria; d, duct of gland cell; g, genital rudiment; gm, germ mass; i, intestine; o, opening of ducts of gland cells; pg, posterior gland cell; ph, pharynx; vs, ventral sucker; yg, yellow granules.

ON A NEW SPECIES OF POTORUS (MARSUPIALIA) FROM A CAVE DEPOSIT ON KANGAROO ISLAND, SOUTH AUSTRALIA

BY H. H. FINLAYSON

Summary

To the generosity of the late Dr. A. M. Morgan, the South Australian Museum owes a collection of mammal bones taken in the so-called Kelly's Hill caves on Flinders Chase in the south-western portion of the island. While the collection is an interesting one as indicating the former presence on the island of mammals which are now either absent or excessively rare, all the species represented, save one, are identical with, or closely related to, those indigenous to the adjacent South Australian mainland. The exception is found in a single skull of a rat-kangaroo, which is clearly an undescribed species of *Potorus,* allied to the West Australian *P. platyops.*

ON A NEW SPECIES OF POTOROÜS (MARSUPIALIA) FROM A CAVE DEPOSIT ON KANGAROO ISLAND, SOUTH AUSTRALIA

By H. H. Finlayson
Hon. Curator of Mammals, South Australian Museum

[Read 9 June 1938]

Plates V, VI and VII

To the generosity of the late Dr. A. M. Morgan, the South Australian Museum owes a collection of mammal bones taken in the so-called Kelly's Hill caves on Flinders Chase in the south-western portion of the island.

While the collection is an interesting one as indicating the former presence on the island of mammals which are now either absent or excessively rare, all the species represented, save one, are identical with, or closely related to, those indigenous to the adjacent South Australian mainland. The exception is found in a single skull of a rat-kangaroo, which is clearly an undescribed species of *Potoroüs,* allied to the West Australian *P. platyops.*

On searching other collections of Kangaroo Island material in the Museum, a second skull of the same animal, with a part skeleton, has been found. This was forwarded to the Museum from the same cave in February, 1926, by Miss Edith May.

Cranial Characters

Both skulls are damaged and that from the Morgan collection is without a mandible. By a fortunate chance, however, the damage has not affected the same areas in both skulls, so that taken together they give an almost complete version of the cranial anatomy of the animal. Both skulls are from mature or even aged animals, with the secator and M^4 in place, and in both the molar crowns show a considerable amount of wear. One is appreciably larger than the other (see table), and for purposes of comparison with the British Museum specimen of *P. platyops,* measured by Thomas (1), this has been assumed to be a male also, though, of course, it is by no means certain that such was the case.

The skulls are very small and delicate, and the animal evidently shared with *P. platyops* the distinction of being the smallest member of the subfamily, and, indeed, of the whole of the Macropodidae, with the exception of *Hypsipymnodon.* In general shape the skull is quite *Bettongia*-like, roughly comparable to *B. penicillata* for example; the shortened muzzle, smooth outlines and absence of crests making it very unlike an adult of its congener, *P. tridactylus.* That its place is with *Potoroüs,* however, is plainly attested by the characters of the dentition and by the structure of the muzzle region, of the zygomata and of the mandible.

The nasals are relatively shorter than in *tridactylus* and much more expanded posteriorly, though less so than in *platyops.* Their maximum breadth goes but

2·2 times into their length, and their minimum breadth along their junction with the premaxillae, 5·8 times. The general shape of the nasals is similar to that of *platyops*, but both postero-internal and postero-external angles are more acute than in the West Australian species. The posterior portion of the muzzle region is greatly expanded from side to side, but at the maxillo-premaxillary suture is suddenly constricted, and from that point to the anterior nares the nasal chambers are narrow and tubular, with their vertical and transverse diameters about equal. This is a good distinction of *Potoroüs* from *Caloprymnus*, *Bettongia* and *Aepyprymnus*, in all of which the anterior nares show a more or less marked deepening from above downwards, as in the typical Macropodinae. The relative areas of premaxilla and maxilla on the walls of the nasal chambers are about as in *tridactylus*, but the sharp procumbent spur on the anterior margin of the premaxillae in the latter species is absent or only slightly indicated.

The frontal and interorbital region is quite parallel-sided and remarkably broad; even more so than in *platyops*. In the larger of the two skulls the interorbital width is nearly half the maximum width of the skull across the zygomata. The supraorbital margins are smooth and rounded, but in the larger skull there is a slight tuberosity at the site of the post-orbital process. The brain case is deeply vaulted and very smoothly rounded, the temporal ridges but slightly indicated, the sagittal crest absent and the lambdoids very slight. The contours of this part of the skull are practically those of a very young *tridactylus* at the M^1 stage.

The plane of the occiput is less oblique to the basi-cranial axis than in *tridactylus*, and does not differ notably from that in some *Bettongia*. There is a thin crescentic interparietal. The paraoccipital processes scarcely exist as free projecting elements, but are bent forward and closely applied to the posterior border of the bullae, as in some Peramelidae. The alisphenoid bullae are much more expanded than in *tridactylus*, but variably so in the two skulls—the smaller having considerably the larger bullae. In this example the antero-posterior diameter of the expanded portion is 9 mm., the transverse diameter 5·6 mm., and its projection below the level of the lower margin of the tympanic annulus 4·2 mm.

The zygomatic arch is curiously shaped in a lateral view. The anterior root of the malar is broad and powerful, but rapidly narrows to a thin weak infraorbital bar. The upper margin of the squamosal portion is feebly concave and it slopes down to the posterior root, though much less steeply than in *tridactylus*. The squamosal makes a wide contact with the frontal.

The posterior palate has been damaged in both skulls, but the pterygoid fossae seem to have been shallower than in *tridactylus* and, therefore, much shallower than in the rest of the subfamily. The palatine vacuities are longer, extending forward to the front of M^2 in one skull and the middle of M^1 in another. Anterior palatal foramina very small, as in *platyops*.

The mandible shows the typical *Potoroüs* characters of slenderness, comparatively straight inferior border, a weak coronoid process meeting the alveolar border at a wide angle, and a condyle relatively large, expanded from side to side, and with its antero-internal angle produced to a spur.

Dentition

All the teeth of the adult dentition are represented in either one or other of the two skulls, except the upper second and third incisors. All the teeth are considerably worn, and the finer detail of crown pattern in most cases lost. In the upper series the first incisor is a comparatively short broad tooth, showing none of the exaggerated styliform specialization of *tridactylus;* it projects beyond the alveolar margin only about 3 mm., as against 8 mm. in *tridactylus,* but resembles its larger ally in that its anterior surface is nearly vertical and lacks the more or less marked recurvature of all the other genera. In *platyops* this tooth is stated to be "very long" (Thomas). The alveoli of the missing second and third incisors indicate minute teeth.

A single detached canine is a fairly strong functional tooth of about the same relative proportions as in *tridactylus.* The secator is a reduced version of that of *tridactylus;* the anterior lobe strongly developed into a subconical cusp projecting well below the general level of the blade; the outer surface strongly emarginate and bearing two broad shallow grooves; the long axis parallel to the basi-facial axis of the skull. The molar rows are less straight than in *tridactylus,* converging gently towards M^4. $M^2 > M^1 > M^3 > M^4$. The crowns of all the molars are squarer and less elongate antero-posteriorly than in *tridactylus;* their surfaces smooth through wear, but originally quadri-tubercular and their pattern very similar to *tridactylus* and the primitive species of *Bettongia.* M^4 a relatively smaller tooth than in *tridactylus;* its crown area little more than that of the posterior lobe of M^3. The posterior lobe of M^4 reduced, but distinctly bifurcate.

In the mandible the incisor is a broad, somewhat round-pointed tooth, more spatulate than in most of the Potoroinae and without the upward phalangerine curvature of *tridactylus* and *platyops.* P^4, 3·9 mm.; obscurely 2-grooved. M^1, quadricuspid. $M^2 > M^3 > M^1 > M^4$.

In comparing the skull characters of the present form with those of *P. platyops,* I have had to rely entirely upon the first description of Waterhouse (2), of Thomas *(loc. cit.,* 121) and the supplementary remarks of Bensley (3) upon the dentition. These notices, together with the single figure of Thomas, leave the skull of *platyops* still very imperfectly described, and many details which would have amplified the comparison are lacking. The chief differences which have been brought to light may be summarized as follows: 1, the nasals in the South Australian animal are longer, less expanded posteriorly, and with slightly different conformation of their posterior margins; 2, the interorbital region is wider; 3, the palate is longer; 4, the molar rows are longer; 5, the first upper incisor is shorter; 6, the lower incisor is more specialized and lacks some of the phalangerine characters of *platyops.*

While it is obvious that the Kangaroo Island form is closely allied to the West Australian *platyops,* and possible that the first four differences might disappear if adequate series of both could be measured, five and six appear to be true structural differences indicating differing degrees of specialization. Moreover, the two localities (Kangaroo Island and Albany) are over 1,000 miles apart, and while *platyops* is (or was in 1840) a living species, the circumstances of the present find necessitate one regarding it as a fossil or subfossil form, with the possibility of a considerable antiquity[1] in post-Pleistocene time. For these reasons I propose to distinguish it under the name *Potoroüs morgani* with a part skull without mandible, registered number P. 3413, and a part skull with mandible, registered number P. 168, as cotypes of the species, in the South Australian Museum.

Associated with the larger skull is a part skeleton forwarded at the same time. With the exception of three fragments evidently derived from a larger animal, possibly *Trichosurus,* these bones are in the same condition of preservation as the skull and show the same characteristic surface spattering (since removed). They exhibit, moreover, morphological characters which place them unmistakably with *Potoroüs,* and that they are derived from the same animal that furnished the skull, I believe to be beyond reasonable doubt. Though I propose to found the species, so far as diagnosis is concerned, upon cranial characters alone, some account of the rest of the skeleton may be of interest, as those of *gilberti* and *platyops* have never been examined, and the osteology of *Potoroüs* as recorded, thus rests entirely upon the existing species, *tridactylus,* regarded by Bensley as a comparatively specialized form.

The bones, like the skull, give evidence of considerable age in the animal furnishing them, and in the examination which follows they have been compared with a skeleton of a similarly aged male of *tridactylus* from Tasmania, and with skeletons of three other Victorian examples at varying stages of immaturity. Wherever dimensions are given for *tridactylus,* however, they are derived from the aged male alone. All dimensions in millimetres.

The fore limb

The clavicle, scapula, humerus, radius and ulna of both sides are present, but the manus is represented only by a carpal element and some phalanges.

The *clavicle* has a maximum length across the arc of curvature of 14·3, as against 24·1 in *tridactylus.* It is of the same general form but more strongly and suddenly expanded at the sternal extremity, and wider also below the attachment to the acromion.

The *scapula*—Maximum length, 34·3; maximum breadth, 12·4. Somewhat narrower than in *tridactylus,* the ratio length/breadth 2·7, as against 2·3. The

[1] The appearance of the bones does not encourage this idea so far as the present specimen is concerned. They are quite unmineralized and, when cleaned from some surface spatterings, quite unstained and have a very "recent" look. It is possible that the animal may have persisted on the island till quite recent times, or even still be extant there.

supra-scapular border more rounded, its angle with the glenoid border less acute, and the anterior border approaching the coracoid, less deely emarginate.

The *humerus*—Maximum length, 31·1; distal breadth, 8·1; proximal breadth, 6·7. Agreeing closely with immature bones of *tridactylus* in structural features and proportions, but the shaft relatively more slender than in the adult of that species, and less expanded distally. The proportion of distal expansion to length is 3·8, as compared with 3·3 in the larger animal.

The *radius*—Length, 38·1. Much as in *tridactylus,* in which the length is 51·8.

The *ulna*—Maximum length, 45·8. *Tridactylus* 64 (ca.). The shaft more slender, somewhat rounder in section, and less flattened from side to side; tapering rapidly distally to a very delicate styloid process. The anconeal process appearing massive in comparison with the distal part of the bone, but its proportion to the bone as a whole much the same in both species. Immediately distad to the coronoid process of the notch, its lateral surface is conspicuously hollowed out over a space of 6 mm., beyond which the surface is distinctly ridged for a like distance—neither feature marked in the larger animal.

The proportion which the length of scapula, humerus and ulna individually bear to the limb as a whole is exactly the same in both species.

The *pelvis*—The following figures give the chief dimensions of this bone in *morgani* and *tridactylus,* respectively. The number in brackets is the quotient obtained by dividing the maximum length by the value in question. This arrangement is adopted in the succeeding sections as well. Maximum length, 54·1, 83·8; ischial breadth, 31·9 (1·7), 54·9 (1·5); acetabular breadth, 30·5 (1·7), 50·0 (1·7); illiac breadth, 33·2 (1·6), 56·0 (1·5); length of pubic symphysis, 21·9 (2·5), 34·0 (2·5).

The pelvis presents several minor points of distinction. It is proportionally longer and narrower, the ischial tuberosity is more developed, the illiac wing tapers to the extremity, and the pubics along the symphysis are much narrower and more fragile, with a corresponding alteration in the shape of the obturator foramen.

The epipubic of the right side has been preserved (detached); in shape and relative size much as in *tridactylus;* its maximum length 10·7, and width 3·3.

The hind limb

This is represented by femur, tibia and fibula of both sides, quite undamaged, and by a number of pedal elements.

The *femur*—The chief dimensions of this bone in *morgani* and *tridactylus* are as follows: greatest length, 56·3, 85·4; proximal breadth across the trochanters, 10·5 (5·3), 16·2, (5·3); diameter of head, 4·3 (12·0), 8·3 (10·3); distal breadth, 9·6 (5·8), 14·0 (6·1); minimum (antero-posterior) diameter of shaft, 4·0 (14·1), 7·8 (11·0).

The femur is thus in close agreement with that of the larger species in its main proportions, but is more slender; the minimum diameter of the shaft going 2·6 times into the maximum breadth across the trochanters, as against 2·0 in *tridactylus.* The disproportion between the antero-posterior and transverse diameters is also greater in *morgani*, the bone being more distinctly compressed from side to side. The head is less developed, and so also is the tuberosity on the posterior surface of the shaft.

The *tibia*—Maximum length, 64·1, 95·6; proximal breadth, 9·8 (6·5), 14·8 (6·5); distal breadth, 6·8 (9·0), 10·5 (9·1); minimum breadth, 2·8 (23), 5·5 (17). The structural features concerned with articulation and muscular attachment are practically those of *tridactylus* in miniature. As with the femur, however, the shaft is more slender in comparison with the extremities. Its medial outline, as seen from behind, is slightly less sigmoid, and on the anterior border the notch below the tuberosity is deeper.

The *fibula*—In this bone the agreement in proportion is less exact, but no considerable differences can be made out. Maximum length, 62·0, 92·7; proximal breadth, 4·5 (13·7), 7·5 (12·3); distal breadth, 3·6 (17·2), 5·8 (16).

The *pes*—Twenty elements derived from both left and right feet are represented. Neither extremity can be reconstructed from them, but the main axis of the left foot can be laid down sufficiently accurately to give the approximate length of the pes.

Length of pes, 58·0, 90·5; calcaneum, 11·6 (5·0), 17·2 (5·2); second metatarsal, 21·5 (2·7), 26·9 (3·4); fourth metatarsal, 25·0 (2·3), 32·7 (2·8); first phalanx of fourth digit, 11·7 (4·9), 15·8 (5·7). In *morgani* the fourth metatarsal makes a larger contribution to the length of the foot than in *tridactylus*, presumably with a corresponding reduction in the astragalus and second and third phalanges, and the metatarsals of the syndactylus digits also show a similar elongation.

The changes in the appendicular skeleton, which occupy a prominent place in the evolution of the Macropodidae from the Phalangeridae, are somewhat less important in *Potoroüs* than in the other genera, owing to the early adoption of comparatively sedentary, and in the case of *tridactylus*, partially fossorial habits. Nevertheless, the specialization of the hind limb has already gone so far that careful comparisons of the proportional dimensions of the limbs and their segments might well be expected to bring to light any considerable differences in the phylogenetic standing of the two species under consideration. The most important of the relationships which can be deduced from the figures are:

(1) The proportional contribution of each of the three segments to the total length of both fore and hind limb. Under this head five out of the total six sets of segments have been tested, and the agreement between the two species found to be very close. The greatest divergence is in the pes, where it amounts to no more than 3%.

(2) The length of the fore limb in relation to the general bodily size of the animal. In assessing this relationship, I have taken the length of the vertebral column from atlas to sacrum (inclusive) as a rough index of the size of the animal, and expressed the length of humerus, plus antibrachium, as a percentage of it. This gives 50% for *morgani*, 46% for *tridactylus;* a relative superiority of about 8% in the fore limb of the smaller animal.

(3) The length of hind limb in relation to the general bodily size of the animal. Here the agreement is almost exact, the percentages being: *morgani,* 115%; *tridactylus,* 116%.

(4) The relative disproportion in length of fore and hind limbs. It follows, from (2) and (3), that the ratio of fore to hind limb in *morgani* is as 1:2·3, and in *tridactylus* 1:2·5. In the Phalangeridae the subequal or superior fore limb is the rule, and the sole evidence of the retention of primitive characters in the limbs of *P. morgani* is, therefore, this 8% reduction in the superiority of the hind limb, as shown by the most "advanced" species, *tridactylus.*

Ribs—Twenty are represented, of which 11 are from the left side, the absentees being the eighth and thirteenth.(2) The maximum length across the arc of the first and sixth are 9·9 and 31·9, and in *tridactylus* 14·8 and 49·2, respectively. They agree closely with those of the larger species.

Vertebrae—Thirty-seven elements are present, representing 4 cervicals, 12 thoracics, 6 lumbars, the sacrum, 5 precaudals, and 9 caudals. As a disarticulated column of a sufficiently aged *tridactylus* is not available, comparison of a single accessible dimension of one vertebrae in each of five groups has been made. (The figures in brackets are the quotients of the values for *tridactylus* divided by those for *morgani.)*

Maximum transverse width of atlas, 14·1 (1·0), 23·3 (1·6); maximum height of first thoracic, 17·3 (1·0), 33·2 (1·9); maximum transverse width of sixth lumbar, 6·8 (1·0), 31·2 (1·8); maximum transverse width of sacrum, 18·9, (1·0), 32·6 (1·7); maximum transverse width of second precaudal 16·3 (1·0), 28·7 (1·7).

The disproportion between the two species is greatest in the thoracic series and is due chiefly to the exaggerated development of dorsal spines in *tridactylus.* This is, no doubt, correlated with a heavier nuchal musculature, which, in turn, is a response to the much longer and heavier head and to the greater development of the habit of rhinal excavating.

Sternum—This is represented by the manubrium, intact. It agrees exactly in form with the same segment in two immature skeletons of *tridactylus* from Victoria, but differs from the aged Tasmanian example. In the manubrium of this specimen two pairs of lateral processes are developed—possibly as an abnormality, however, as the bone is warped and unsymmetrical. Maximum breadth, 12·0 (1·0), 19·1 (1·6).

Bensley *(loc. cit.),* from a study of the dentition of *P. platyops, P. gilberti,* and *P. tridactylus,* was lead to a belief in the much more primitive position of the former, as "a form which shows an interesting approximation in many of its dental and cranial characters to *Petaurus,* suggesting an affinity with *Gymnobelideus,*" etc., etc.

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(2) Assuming 13 to be the normal number as in *tridactylus.*

While an intimate comparison of the skulls of *morgani* and *platyops* has not been possible, enough has been done in this direction to suggest that the two are upon much the same evolutionary level. It is somewhat surprising, therefore, on extending the comparison to skeletal characters, to find a relatively close correspondence between *morgani* and the much larger, (and in cranial anatomy) more specialized *tridactylus*. Though there are definite minor structural differences to be seen, and minor differences in proportion have been demonstrated, these are mostly of a kind to be associated with inferior size, weight and musculature, and surface, rather than subsurface feeding habits. The attempt to disclose a greater residuum of primitive phalangerine characters in the smaller animal by systematic mensuration, has served chiefly to emphasise the close detailed correspondence of bone for bone; a correspondence which might well be further increased if the range of individual variation could be taken adequately into account.

On the whole (if *morgani* can be taken as representing *platyops*), it would appear that the osteology of *Potoroüs* as a genus is at least as stereotyped as that of *Bettongia*, and that the differentiation of *tridactylus* from the smaller species is a comparatively superficial and perhaps very recent change.

Skull Dimensions of **Potoroüs morgani** sp. nov., in comparison with those of P. platyops (Gould)

Columns 1 and 2 Skull dimensions of the cotypes of *P. morgani* (in m.m.s.)
Column 3 Skull dimensions of the type (♂) of *P. platyops* (in m.m.s.)
Column 4 Mean skull dimensions of the cotypes of *P. morgani* expressed as percentages of the basal length
Column 5 Skull dimension of *P. platyops* as percentages of the basal length

	1	2	3 (3)	4	5
Dental condition	P^4M^4	P^4M^4	P^4M^4		
Greatest length	57·4	61·3	—	—	—
Basal length	47·8	51·5 (ca.)	50	100	100
Zygomatic breadth	32·3 (ca.)	35·1	35	67·9	70·0
Nasals: length	—	25·0	24	50·4	48·0
Nasals: greatest breadth	11·5 (ca.)	11·0	13	22·6	26·0
Nasals: least breadth	4·3 (ca.)	4·3	4·6	8·6	9·2
Depth of anterior nares	8·9	—	—	17·9	—
Interorbital constriction	15·0	16·2	14·6	31·4	29·2
Palate: length	30·5 (ca)	34·7 (ca.)	30	65·7	60·0
Palate: breadth inside M^2 (4)	8·8	9·4	10	18·3	20·0
Anterior palatine foramina	2·0	—	2·1	4·0	4·2
Diastema	8·1	—	7·8	16·3	15·6
Basicranial axis	15·0 (ca.)	15·1	—	—	—
Basifacial axis	33·0	36·5	—	—	—
Facial index	220	241	—	230·5	—
Ms^{1-3} length	9·8	9·8	8·9	19·7	17·8
P^4 length	—	5·0	4·9	10·0	9·8
M^4 length	2·0	2·0	2·1	4·1	4·2

(3) Ex O. Thomas
(4) Anterior lobe

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EXPLANATION OF PLATES V, VI, VII

illustrating the osteology of **Potoroüs morgani** sp. nov.

All figures approx. x 1-2

Plate V

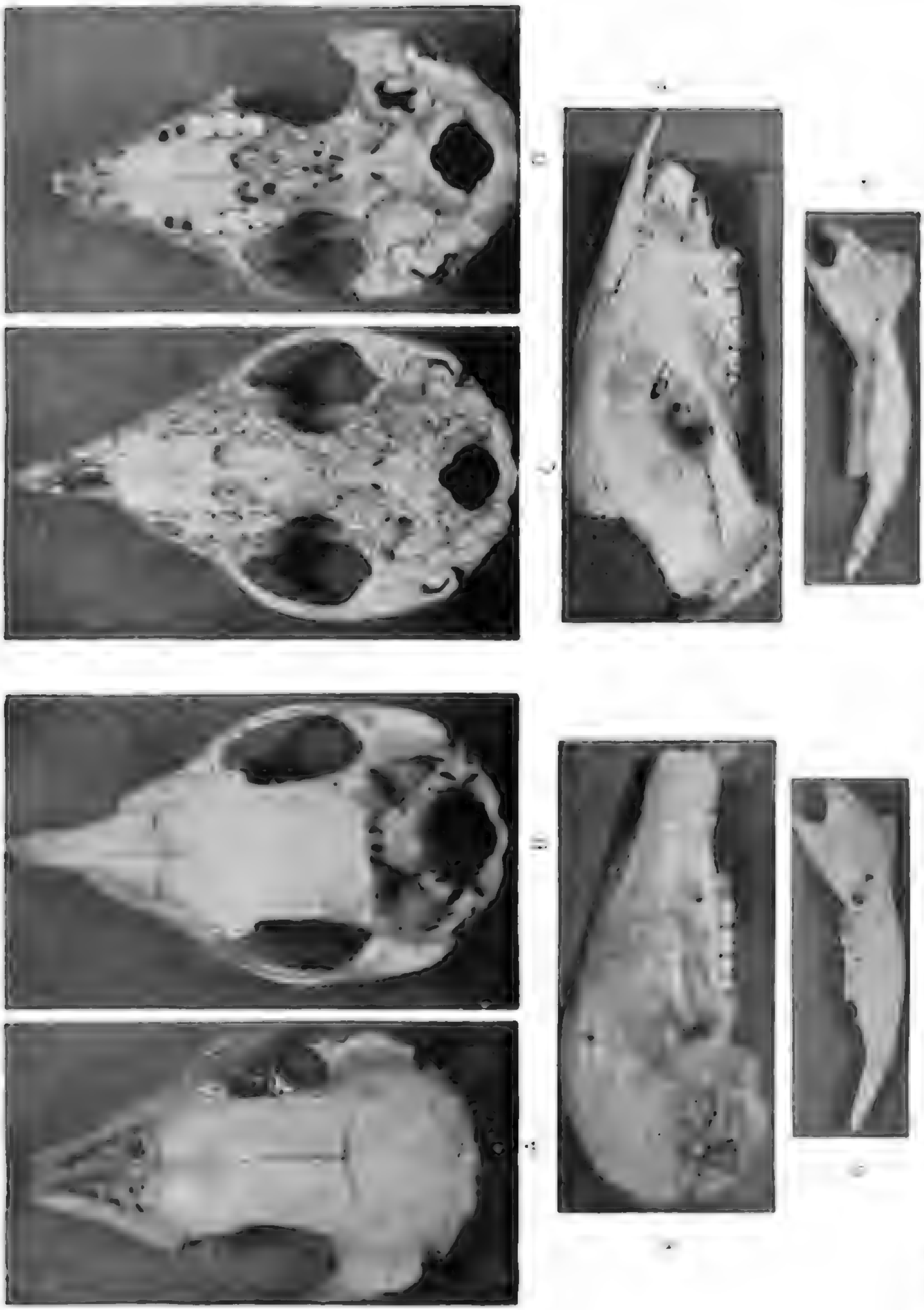
Figs. A and B Superior views of the skulls of the cotypes
Figs. C and D Palatal views of the same
Figs. E and F Lateral views of the same
Fig. G. Outer aspect of a left mandibular ramus
Fig. H Inner aspect of a right mandibular ramus

Plate VI

Fig. I Posterior view of right femur
Fig. J Anterior view of right tibia
Fig. K Anterior view of right femur
Fig. L Outer (lateral) view of right tibia
Fig. M Outer (lateral) view of right fibula
Fig. N Dorsal view of calcaneum of right pes
Fig. O Dorsal view of fourth metatarsal of right pes
Fig. P Dorsal view of first phalanx of right pes
Fig. Q Dorsal view of pelvis
Fig. R Ventral view of pelvis
Fig. S Ventral view of right epipubic
Fig. T Lateral (outer) aspect of right scapula
Fig. U Anterior aspect of right humerus
Fig. V Lateral aspect of right radius
Fig. W Lateral aspect of right ulna
Fig. X Antero-dorsal aspect of right scapula
Fig. Y Postero-lateral aspect of right humerus
Fig. Z Medial aspect of right ulna
Fig. A Medial aspect of right radius

Plate VII

Figs. B to L Ventral aspect of the ribs of the left side; the eighth and thirteenth (?) absent
Fig. M Dorsal view of a caudal vertebra
Fig. N Dorsal view of the first precaudal vertebra
Fig. O Dorsal view of the sacrum
Fig. P Anterior view of the sixth lumbar vertebra
Fig. Q Anterior view of the first thoracic vertebra
Fig. R Ventral view of the presternum
Fig. S Anterior view of the atlas



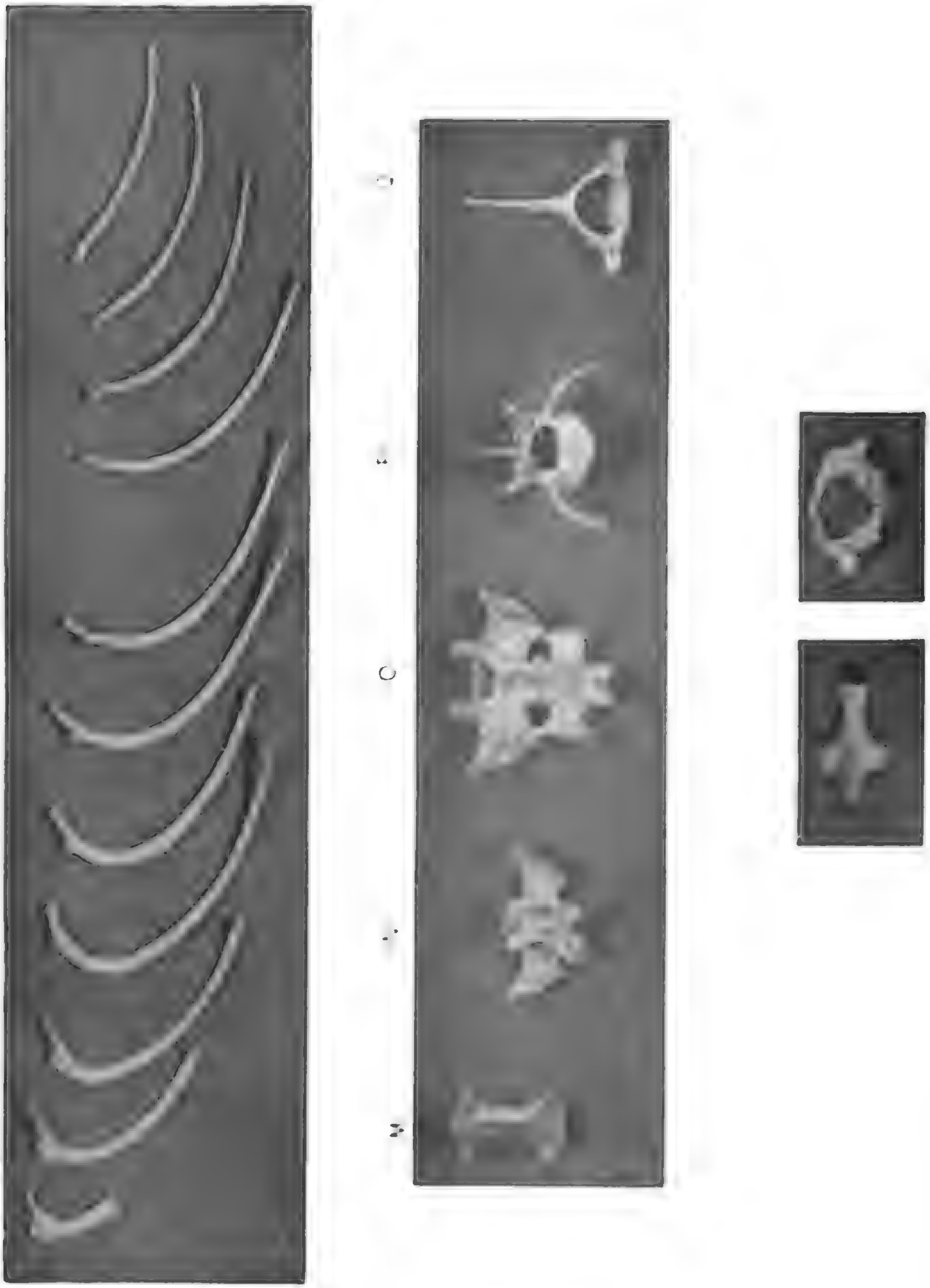
S R Q

X Y Z

P O N M L K J I

T U V W

Photo, H. H. Finlayson



Photo, H. H. Finlayson

ON THE ECOLOGY OF THE GROWTH OF THE SHEEP POPULATION IN SOUTH AUSTRALIA

BY J. DAVIDSON

Summary

Considerable attention has been focussed, during recent years, on the biology of animal populations. Several investigators have studied, quantitatively, the influence of various factors affecting the growth of populations. For each species of animals in an area, the number of individuals varies from time to time, according to the intensity of the struggle going on between the forces which enable the species to reproduce and the physical and biotic forces in the environment; the latter may favour the birth rate and survival rate during certain periods and depress them during other periods. In order to make a quantitative study of the growth of natural populations it is necessary, therefore, to obtain a census, from lime to time, of the individuals composing the population. In a natural environment great difficulty is experienced in obtaining reliable samples representative of the population in a given area at the time the samples are taken. It has been shown by several experimenters, notably by Raymond Pearl and his associates, that in the "closed" system of a laboratory experiment, the growth of a population follows a definite course, which appears to be clearly represented by the Verhulst-Pearl logistic curve (5). Pearl and Reed (6) applied this curve in order to interpret the course of the growth of human populations; Belz (1) applied the same principles to the population of Australia.

ON THE ECOLOGY OF THE GROWTH OF THE SHEEP POPULATION IN SOUTH AUSTRALIA

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[Read 9 June 1938]

I Introduction

Considerable attention has been focussed, during recent years, on the biology of animal populations. Several investigators have studied, quantitatively, the influence of various factors affecting the growth of populations. For each species of animals in an area, the number of individuals varies from time to time, according to the intensity of the struggle going on between the forces which enable the species to reproduce and the physical and biotic forces in the environment; the latter may favour the birth rate and survival rate during certain periods and depress them during other periods. In order to make a quantitative study of the growth of natural populations it is necessary, therefore, to obtain a census, from time to time, of the individuals composing the population. In a natural environment great difficulty is experienced in obtaining reliable samples representative of the population in a given area at the time the samples are taken. It has been shown by several experimenters, notably by Raymond Pearl and his associates, that in the "closed" system of a laboratory experiment, the growth of a population follows a definite course, which appears to be clearly represented by the Verhulst-Pearl logistic curve (5). Pearl and Reed (6) applied this curve in order to interpret the course of the growth of human populations; Belz (1) applied the same principles to the population of Australia.

The growth of a sheep population is subject to the controlling influence of the sheep farmer. The position in South Australia is of interest, since the genial climate permits of the sheep leading a comparatively free life, and a century of annual records of the sheep numbers are available. Prior to 1836, when the Province of South Australia was founded, the inhabitants of the country were aborigines who did not practise agriculture. Therefore, the natural vegetation was undisturbed, except for light grazing by marsupials and occasional bush fires. The early settlers imported sheep from Tasmania and elsewhere to form the beginnings of the sheep industry. At the end of 1838 there were 380,000 sheep in the Province. The pastoralists aimed at increasing their flocks, so as to occupy the expanding area of grazing land which was gradually being opened up in the virgin country. It was necessary to protect the sheep from natural enemies such as wild dogs (dingoes), and later on from foxes and blowflies. The introduced rabbit *(Oryctolagus cuniculus)* increased rapidly in numbers after about 1870; an Act of Parliament was passed in 1875 "to provide for the suppression of the rabbit nuisance." It is not possible from the data available to assess, quantitatively, the effect of these biotic factors on the growth of the sheep population.

When all the areas in the Province suitable for sheep-raising had been occupied, it would be expected that the sheep population would attain a saturation density. The number of sheep would be determined primarily by the "permanent" feeding value, or "carrying capacity" of the pastures; the latter would depend, to a great extent, on the management of the pastures in this respect. Economic factors, associated with supply and demand of the products of the sheep industry, would also exert an influence.

The object of the present paper is to examine the annual records of sheep numbers for South Australia, and interpret the growth of the population in terms of the Verhulst-Pearl logistic curve.

II Fitting the Data to the Verhulst-Pearl Logistic Curve

The annual numbers of sheep in South Australia since 1838 are given in the published livestock statistics prepared by the Government Statist. Records were not taken for the eleven years 1841, 1851, 1855, 1885-8, 1893-5 and 1906, but reliable estimates are available for these years. The number of sheep for each year is plotted in figure 1. The average annual number for each five-year period since 1838 is given in Table I; in each case the number is allotted to the mid-year for the period.

Table I

Showing the Average Annual Sheep Population in South Australia for Five-year Periods, commencing 1838; and the Calculated Values

Mid-year (x)	Population in Thousands (y)		Mid-year (x)	Population in Thousands (y)	
	Observ.	Calc.		Observ.	Calc.
1840	177	303	1890	6926	6921
1845	527	570	1895	6314	7014
1850	1095	1031	1900	5162	7063
1855	1835	1769	1905	6170	7087
1860	2887	2795	1910	6250	7108
1865	4033	3913	1915	4512	7111
1870	4628	5057	1920	6297	7113
1875	6029	5888	1925	6908	7115
1880	6432	6429	1930	6714	7115
1885	6588	6746	1935	7918	7115

The data given in Table I have been fitted to a logistic curve, having the formula:

$$y = d + \frac{K}{1 + e^{a - bx}}$$

where y = population; x = time (year); d = 0; K = distance between the upper and lower asymptote; e = 2·71828 (base of Naperian logs); a and b are calculated constants. The value K = 7115·3 (thousands) was calculated from the average sheep numbers for 1850, 1865 and 1880. For each of the observed values for y, and the appropriate values for x from 1845 to 1880 (Table I), the values of $\log \frac{K - y}{y}$ were calculated. These values were fitted to a straight line by the method of least squares for eight observations. The formula for the line is y = a + bx where a = 1·351005 and b = − 0·29031.

Taking the values for $\log \frac{K - y}{y}$ when x = 1845 and 1875 respectively, and changing these values into Naperian logarithms (N), the constants *a* and *b* in $1 + e^{a - bx}$ were calculated, by substituting the appropriate values for x and N in the formula:

$$N = a - bx$$

This gave a = 249·106686; b = 0·133693. Substituting these values in the formula:

$$y = d + \frac{K}{1 + e^{a - bx}}$$

we obtain the calculated logistic curve

$$y = \frac{7115 \cdot 3}{1 + e^{219 \cdot 106686 - 0 \cdot 133693x}}$$

The curve is shown in figure 1; the observed and calculated values for the population (y) are given in Table I.

The curve illustrates the trend of the population up to about 1890, when the density approximates to its upper asymptote (7115·3 x 1000). This is the theoretical saturation density for the sheep population under the environmental conditions obtaining up to that time. It might be expected, with a stable environment, that the future population would oscillate about this density, but the extensive fluctuations after this date (fig. 1) show that profound changes must have taken place in the environment. These changes and their influence on the population are discussed in the next section.

III Progress of the Sheep Population

South Australia has an area of 380,000 square miles, of which 83%, consisting of the northern portion of the State, has an annual rainfall of less than 10 inches. The characteristics and distribution of the native vegetation are primarily related to rainfall; apart from economic considerations, the availability of food (pasture) and water are the major factors affecting the progress and distribution of the sheep population (8).

The gradual opening up of the savannah woodland and sclerophyll forest by the early settlers afforded excellent pasturage for sheep; the clearing of the mallee lands came later with the development of wheat farming. The flocks gradually progressed northwards into the saltbush steppe and by 1866 had extended to about the thirtieth parallel of latitude, a northern limit determined

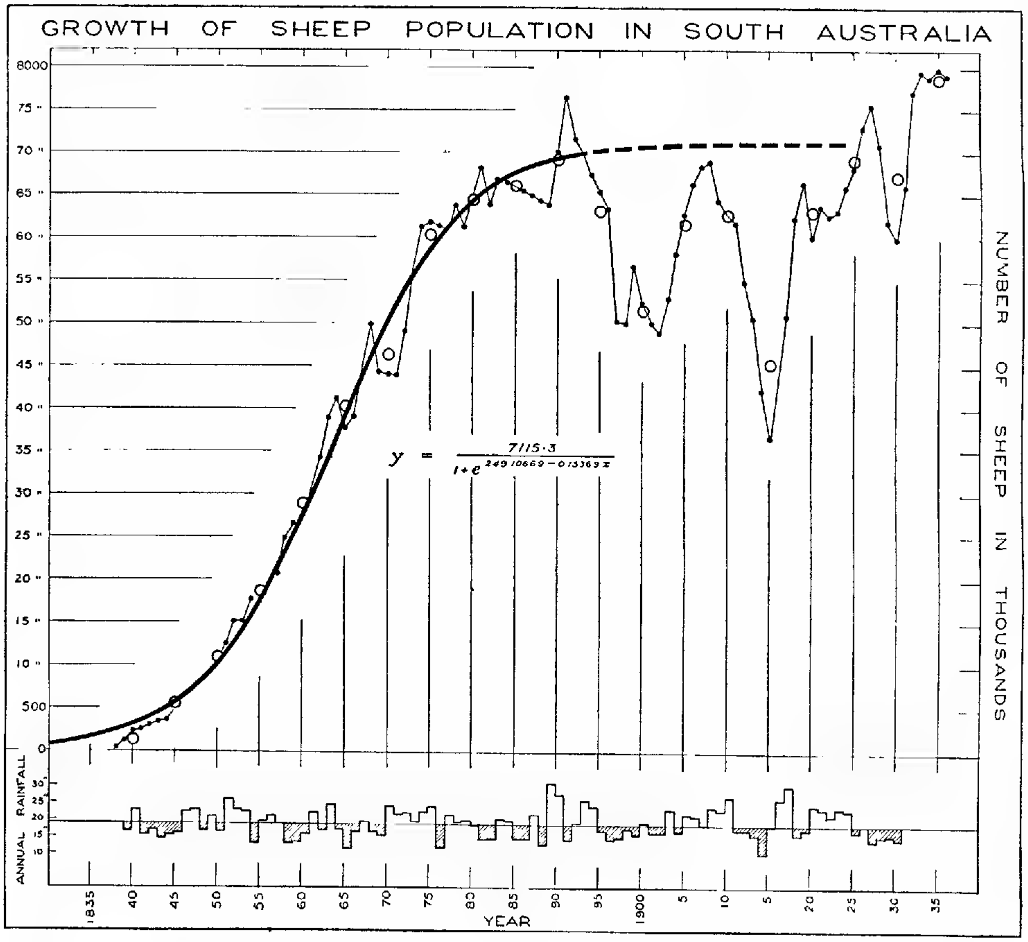

Fig. 1

The sheep numbers taken from official records are shown for each year (small black circles); the average number for 5-year periods, since 1838, are also shown (larger, open circles). The rainfall for the years 1839-60 on the Adelaide Plains is shown; from 1860 onwards the rainfall data are for the Lower North (Central) districts. The shaded area shows the years in which rainfall was below the average

by rainfall and distance from the occupied areas (7). With the proclamation of the first counties in 1842, the area under cultivation, particularly for wheat, gradually extended; by 1891 approximately $2\frac{1}{2}$ million acres were under cultivation (3, 7).

Rainfall plays a dominating part in producing fluctuations in the number of sheep from year to year, due primarily to its effect on the pastures. In figure 1 is shown the annual rainfall for 1839-60 over the Adelaide Plains; and for 1860-1931 over the Lower North (Central) district of South Australia. The rainfall figures were taken from the official publication of the Commonwealth Bureau of Meteorology, "Results of Rainfall Observations made in South Australia and the Northern Territory," by H. A. Hunt, 1918, 17; additional data were kindly supplied by Mr. E. Bromley, Government Meteorologist for South Australia. The shaded portions of the graph indicate the years and amount in which the rainfall was below the average of 18·4 inches and 18·6 inches, respectively. The rainfall for these restricted regions does not give a complete picture of the annual march of precipitation over the whole of the State; but the chart shows those years in which the State received adequate rains, and those in which it experienced dry conditions. There is considerable agreement between dry years and the reduction in sheep numbers; for instance, during the periods 1895 to 1902, 1911 to 1915, and 1926 to 1930.

(a) Period 1838-1891

The population follows closely the trend of the calculated curve throughout this period. The sheep numbers for 1838 and 1839 are dominated by importations and fall below the calculated curve. From 1840 to 1868 they follow the curve closely, and the dry years appear to have had little effect in reducing the population. This may be attributed to the extensive, unoccupied country available for grazing during this early period. For this reason, cattle, which attained their maximum numbers of 375,000 in 1860 and rapidly fell away again, do not appear to have entered seriously into competition with sheep for pasture. The fall in the population during 1869-72 is associated with the dry years, 1868, 1869, and the economic depression which obtained during this period (3). The persistent fall in the population during 1884-89 is related to the dry years of the 1880's; under the influence of good rains in 1889-90 the numbers again rose rapidly. At the end of 1891 there were 7,646,239 sheep in the State, a density which was not attained again until forty years later. Adequate feed (pasture) appears to have been available about 1891 to support this density for a time. Considering the rapid fall of the population in the following years, it is evident that the pastures could not support this density permanently. The saturation density which might be expected from the calculated curve is 7,115,300. It is seen from Table I that the values of the five-year averages for 1895, 1905, 1910 and 1920, lie about a straight line drawn through the average value (6285·75 thousands) for these four periods (the mid years 1900 and 1915 have been excluded, because they represent the population during severe periods of drought). The average value 6285·75 (thousands) for the above periods is 856·55 thousands less than the upper asymptote of the calculated curve. It may be concluded that the conditions obtaining throughout these years tended to keep the population about this lower level, whereas we would expect from the trend of the growth of the population up to 1890 that the ultimate density would oscillate about a value of 7115·3 thousands. The maintenance of the population about this theoretical value would, however, depend upon the stability of the environment, particularly with regard to the food factor; but the amount of feed available in the pasture areas fluctuates considerably, owing to the character of the rainfall (2, 8). The following features associated with the development of the sheep industry appear to have played an important part in keeping the population at the lower level after about 1890.

(a) By 1890 practically all the suitable grazing areas in the State had been occupied. In certain areas, particularly in the more arid districts, the sheep had heavily grazed much of the perennial native vegetation, and regeneration was slow owing to the arid conditions; this reduced the sheep-carrying capacity of these areas. In the regions having more reliable rainfall, certain of the earlier grazing areas were gradually taken up for cultivation with the development of agriculture.

(b) The marked increase in the number of rabbits after about 1870 introduced an additional factor which assisted in reducing the carrying capacity of the pastures.

(c) The pastoralists developed an improved type of sheep by means of selection and "culling," which grew a heavier fleece, so that fewer sheep could be carried on the pastures, for an equivalent weight of wool, compared with the earlier types.

(b) Period 1891-1902

With the exception of a temporary rise in 1899 and 1900 the sheep numbers show a persistent decline during this period, which continued, notwithstanding good rains in 1893-4. The whole decade of the 1890's appears to have been a period of great economic stress in South Australia (3). The situation was accentuated by the succession of dry years from 1895 to 1902 which resulted in the most devastating drought in the history of the State. Agriculture was pushing out into the lesser rainfall areas and the difficulties of climate and agricultural practice were becoming more pronounced.

(c) Period 1902-1908

Under the influence of a succession of good seasons, the population steadily increased during this period to 6,898,451 in 1908. This approximates closely to the calculated saturation density, and notwithstanding the continuation of good rains in 1909 and 1910 the population declined after 1908. It would seem that, under the conditions of agriculture and pasture management obtaining in the State up to that time, the country could not permanently support the density of population which might be expected from the course of the growth curve.

(d) Period 1908-1915

There was a steady fall in the population during this period, which was accelerated during the dry years leading up to the severe drought of 1914.

(e) Period 1915-1936

During the war years, in the early part of this period, the population increased rapidly to 1919, under the influence of good rainfall in 1916 and 1917 and sustained prices for wool. The temporary fall in 1920 is associated with the dry years 1918, 1919. After 1920 the sheep numbers steadily increased to 1927, due to a succession of years with good rainfall and sustained satisfactory wool prices. The pronounced fall in the population from 1928 to 1930 is associated with dry seasons and the drop in wool prices, due to the economic depression of this period. With a return to good seasons after 1930, and the gradual lifting of the depression, the sheep numbers rose rapidly to a record density of approximately 8 millions in 1933, which density has been maintained in subsequent years.

The post war period of agricultural development in Australia is noteworthy for the improvements in pastures and their management. These developments have raised the sheep-carrying capacity of the pastures in South Australia. It will be noted that the reduction in sheep numbers during the adverse years of 1928-30 is less pronounced than in the 1890's and in the years about 1914. This is due to pasture improvements, particularly by the marked increase in the application of artificial manures to natural pastures. The area of top-dressed pastures increased from 250,000 acres in 1928-9 to 900,000 acres in 1936-7. The areas under sown grasses in 1921-2 were practically nil; there were 28,000 acres of lucerne. By 1936-7 there were 250,200 acres of clover, 63,900 acres of sown grasses and 51,700 acres of lucerne. With the development of mixed farming methods during recent years, a greater number of sheep is being carried in association with wheat-growing.

In the arid pastoral regions improvements in water storage and in the management of pastoral properties enable the pastoralist to carry his sheep through drought years more successfully. It should be noted, however, that the increase in sheep numbers during recent years is particularly due to pasture improvements in the agricultural areas. The arid portion of the country north of the 10-inch isohyet carries approximately 21% of the sheep of the State (8).

The first cultural epoch in the pastoral industry, which consisted primarily in stocking the natural pastures, is being replaced by a second cultural epoch, the main features of which are illustrated by the pasture developments referred to above. Under the influence of this new epoch the sheep population is tending to a new growth curve having a higher upper asymptote. It is not possible to predict the trend of this curve at present, owing to the incompleteness of the pasture developments which are in progress.

Summary

The number of sheep present in South Australia, each year from the foundation of the Province in 1836, is given in the published livestock statistics.

These data have been analysed and fitted to the Verhulst-Pearl logistic curve, illustrating the course of the growth of the population. The formula for the curve is:

$$y = \frac{7115 \cdot 3}{1 + e^{249 \cdot 106686 - 0 \cdot 133693x}}$$

The progress of the sheep population during the past 100 years is discussed with reference to this curve. It illustrates that the saturation density of the sheep population, which a natural pasture area can permanently carry, is determined primarily by the feeding value of the pasture, and the regrowth of plants eaten by the sheep. When the density exceeds this value, the balance is upset and the carrying capacity of the area will decline. The effect on the area in this respect will depend upon the degree of overgrazing and the power of the pasture to recover. In the arid climate of South Australia, the recovery is mainly dependent on rainfall and may be considerably delayed.

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A CENSUS OF THE FREE-LIVING AND PLANT-PARASITIC NEMATODES RECORDED AS OCCURING IN AUSTRALIA

BY T. HARVEY JOHNSTON

Summary

The outstanding contributor to the study of Australian free-living and plantparasitic nematodes was the late N. A. Cobb, who was for many years associated with the Department of Agriculture in New South Wales. Most of his work relating to our subject appeared in the Agricultural Gazette of that State (1890- 1902) ; the Proceedings of the Linnean Society of New South Wales (1890- 1898) ; and in the Macleay Memorial Volume (1893), published by the latter Society. Many of Cobb's articles in the Gazette were re-issued as Miscellaneous Publications by the Department, as also was his important paper on “Nematodes, mostly Australian and Fijian” from the Macleay Volume (Misc. Publ. No. 13).

A CENSUS OF THE FREE-LIVING AND PLANT-PARASITIC NEMATODES RECORDED AS OCCURRING IN AUSTRALIA

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The outstanding contributor to the study of Australian free-living and plant-parasitic nematodes was the late N. A. Cobb, who was for many years associated with the Department of Agriculture in New South Wales. Most of his work relating to our subject appeared in the Agricultural Gazette of that State (1890-1902); the Proceedings of the Linnean Society of New South Wales (1890-1898); and in the Macleay Memorial Volume (1893), published by the latter Society. Many of Cobb's articles in the Gazette were re-issued as Miscellaneous Publications by the Department, as also was his important paper on "Nematodes, mostly Australian and Fijian" from the Macleay Volume (Misc. Publ. No. 13). It was in the publications of the Department that Cobb made known his "nematode formula" (1890, 1893, 1898, 1902), and described his differentiator (1890, 1898) which has since been used so extensively as part of a technique for staining, dehydrating and clearing minute and delicate objects, including free nematodes. His papers included several in the Proceedings of the Linnean Society of New South Wales dealing with free nematodes, chiefly marine, from Arabia, Ceylon, the Mediterranean and Western Europe (1890, 1891, 1894). His main article on Australian marine species appeared in 1898. In some of his accounts of plant-parasitic forms (Agr. Gaz. N.S.W.; Macleay Volume), information is given regarding many species which were not then known to occur in Australia.

In the Agricultural Gazette, New South Wales, for 1898 (296-321, 419-454, figs. 1-127), there appeared his "Extract from M.S. Report on the Parasites of Stock." This abundantly illustrated article devotes a great deal of space to free-living species, but, unfortunately, though well figured, there is usually no indication of locality regarding them. Many are known to occur elsewhere than in Australia and, consequently, in the present census there are included only references to the figures of such as are known from information published elsewhere to belong to Australian free-living or plant-parasitic species. Cobb's report was re-published as Miscellaneous Publication No. 215, Department of Agriculture, New South Wales (62 pp.), under the same title, but the cover bears the legend, "Nematode Parasites, their Relation to Man and Domesticated Animals." Two new figures were interpolated and numbered 40 and 47; consequently there is an alteration in the numbering of all figures from figure 40 onwards, when compared with that of the original article. In this census, the original pagination and numbering of figures are quoted.

In 1917 (1918) Miss Irwin-Smith published an excellent anatomical paper dealing with some species of Chaetosomatidae from the coast in the vicinity of

Sydney. Allgen (1927) described a number of Tasmanian marine species from the Derwent River, near Hobart (Brown's River), from material collected during the visit of Larsen's Antarctic (Ross Sea) whaling expedition of 1923-4. Michaelsen and Hartmeyer, in their collecting trip to south-western Australia in 1905, obtained very few free nematodes, judging from Steiner's brief account of them (1916). Most of the remaining references relate to observations by various workers concerning a few species of great economic importance, *e.g.*, some of those belonging to *Tylenchus* or *Heterodera* or allied genera.

Many parasitic nematodes (*e.g.*, Strongylata) have a free-living larval stage, while certain others, such as *Rhabdias* and *Strongyloides*, are heterogamic and have a free stage represented by males and females. Reference is made to the few Mermitidae recorded from the Commonwealth, since maturity is attained in the free living stage. Though the Gordiacea are regarded as only distantly related to true nematodes, the few references to the occurrence of representatives in Australia are included. Plant-parasitic nematodes have received considerable attention from Goodey in his recent book on the group (1933).

The classification utilized in this paper is based mainly on the recent contributions of Filipjev (1934) and of Chitwood and Chitwood (1937). The earliest reference to the presence of free-living nematodes in Australia appears to be that by Whitelegge (Proc. Roy. Soc. N.S.W., **23**, 1889, 307), who in his "List of the Marine and Freshwater Invertebrate Fauna of Port Jackson and the Neighbourhood," stated that numerous species of Anguillulidae occurred in the local fresh waters. The earliest records of plant-parasitic species in the Commonwealth seem to be that of Crawford (1881) relating to ear cockle of wheat in South Australia, and that by Bancroft, whose account of a nematode attacking roots of grape vines and bananas in Queensland, led Cobb (1890, 166) to state that the figures seemed to represent *Tylenchus arenarius*. The latter is a synonym of *T. radicicola* (of authors), more correctly known as *Heterodera marioni*.

Some changes in nomenclature have been made in this paper. *Anguillulina (Fergusobia) tumifaciens* Currie 1937, pre-occupied by *A. tumefaciens* (Cobb 1932) Goodey, is renamed *A. (F.) curriei; Rhabditis allgeni* is proposed for *R. australis* Allgen 1932, nec Cobb 1893; *Monhystera pacifica* for *M. australis* Cobb 1893 (1894), nec Cobb 1893; *Monhystera gracilior* for *M. gracillima* Man 1921, nec Cobb 1893; *M. kreisi* for *M. gracillima* Kreis 1929, nec Cobb 1893, nec Man 1921; *Dorylaimus steinerianus*, for *D. steineri* Thorne and Swanger 1936, nec Micoletzky 1921; *Chromadora cobbiana* for *C. dubia* Cobb 1930, nec Bütschli; *Epsilonematina* for *Epsilonema* Steiner 1931, nec Steiner 1926 (a renaming of *Rhabdogaster* pre-occ.), with type *E. steineri* (Chitwood 1935); *Prochaetosoma* Baylis and Daubney 1926 is pre-occupied by *Prochaetosoma* Micoletzky 1921, and accordingly is replaced by *Epsilonema* Steiner 1926 nec 1931, and the family name Prochaetosomatidae is replaced by Epsilonematidae; Drepanonematidae nom nov. replaces Chaetosomatidae; *Chaetosoma haswelli* Irwin-Smith and *C. falcatum* Irwin-Smith are transferred to *Tristicochaeta*.

Rhabditidae

Anguillula aceti (Mueller), the vinegar eel-worm. Peters (1927) proposed *Turbatrix* to receive it, but Filipjev (1934) doubted the propriety of the change. Though apparently unrecorded from the Commonwealth, it occurs in Brisbane, Sydney, Melbourne and Adelaide, and probably in other parts of Australia.

Rhabditis australis Cobb, Macleay Volume, 1893, 278, from grass, Sydney, New South Wales. Micoletzky, 1921, 252. In 1932 Allgen described *R. australis* n. sp. (Nyt. Mag., Oslo, B, 70, 1932, 192-4), from Campbell Island; but as the specific name is pre-occupied, *R. allgeni* is now proposed for it.

Rhabditis cylindrica Cobb, Agr. Gaz., N.S.W., 9, 1898, 448, fig. 125. No details are given other than those indicated in Cobb's formula and figure. No locality is mentioned, but it is presumably New South Wales. Micoletzky (1921, 258) stated that Cobb's species was possibly only a variety of *R. strongyloides* Schn.

Rhabditis filiformis Bütschli? Cobb, Macleay Vol., 1893, 276-7, pl. 36, from grass, Sydney; Agr. Gaz., N.S.W., 4, 1893, 832-3, fig. 46, from soil around moss roots, Clarence River. Micoletzky (1921, 263) included Cobb's two queried identifications under *R. filiformis,* but pointed out that the figure in the former publication apparently belonged to the species, whilst that in Agr. Gaz., 1893, fig. 46, is that which Cobb had utilized in the Macleay Volume to illustrate *R. monhystera.* Man (Cap. Zool., 1 (1), 1921, 32) stated that Cobb's species was probably distinct from, though closely related to, Bütschli's, because of differences in the sizes of the eggs and of the genital ducts in the two cases. The Australian species requires re-examination.

Rhabditis minuta Cobb, Agr. Gaz., N.S.W., 4, 1893, 831-2, fig. 45, from roots of sugar cane, Clarence River, New South Wales. Micoletzky, 1921, 257.

Rhabditis monhystera Bütschli. Cobb, Macleay Vol., 1893, 278-9, pl. 38, from grass and celery, Australia. Micoletzky, 1921, 253 (syn. *R. simplex* Cobb), 263 (pointing out that Cobb had in error used his figures of this species to illustrate another species, *R. filiformis,* in Agr. Gaz., N.S.W., 1893, fig. 46).

Rhabditis pellioides Bütschli. Cobb, Macleay Vol., 1893, 277, pl. 38, from fresh grass and dead sheaths of banana plants, Australia and Fiji. Micoletzky, 1921, 257.

Rhabditis simplex Cobb, Agr. Gaz., N.S.W., 4, 1893, 830-1, from soil, Clarence River. Micoletzky, 1921, 253, syn. of *R. monhystera.*

Rhabditis sp. Cobb, Macleay Vol., 1893, 256, from celery. See *R. monhystera.*

Rhabditis spp. Heydon and Green, Med. Jour. Austr., 1931, (1), 626, from cultures made from human faeces, North Queensland; one of these coprophilic species was stated to be near *R. hominis.*

Rhabdiasidae

Some Australian frogs, especially *Hyla aurea* in New South Wales and Victoria, harbour lung worms, *Rhabdias* sp., which pass through a free-living generation with distinct males and females.

Strongyloididae

Strongyloides stercoralis (Bavay) has been reported from Australian localities, especially in coastal Queensland, the references having been collected in a recent paper by Johnston and Cleland (Tr. Roy. Soc. S. Aust., 61, 1937, 276). *S. papillosus* (Wedl.) has been recorded from sheep, etc., in New South Wales by Ross and his colleagues, and in Queensland by Roberts. It occurs also in sheep in South Australia. The free-living generation of these two species has not received particular attention in the Commonwealth. Heydon and Green (Med. Jour. Austr., 1931, (1), 626) pointed out the probability of the earlier published infection rates for humans in North Queensland being inaccurate because of the common presence of coprophilic *Rhabditis* spp. in stale faeces.

Diplogasteridae

Diplogaster australis Cobb, Macleay Vol., 1893, 269, from grass, Sydney. Perhaps synonymous with *D. graminum*. Micoletzky, 1921, 406.

Diplogaster graminum Cobb, Macleay Vol., 1893, 270, from grass, Sydney. perhaps synonymous with *D. australis*. Micoletzky, 1921, 406.

Diplogaster trichuris Cobb, Macleay Vol., 1893, 271-2, fig. 3, from grass, Sydney; p. 256, from celery, Sydney. Cobb, Agr. Gaz., N.S.W., 9, 1898, 311, fig. 28, no locality. Tidswell and Johnston, Rep. Bur. Microbiol., N.S.W., 1909, 71. ? *D. trichuris*, banana, N.S.W. Micoletzky, 1921, 405.

Cylindrogasteridae

Myctolaimus pellucidus Cobb, Contrib. Sci. Nematology, 9, 1920, 276, from sheep dung, Moss Vale, N.S.W.; genus stated to be near *Cephalobus;* no specimens preserved. Micoletzky (1921, 209-10), as well as Baylis and Daubney (1926), placed the genus in Cylindrolaiminae. Filipjev (1934) regarded it as a synonym of *Aulolaimus* (Diplogasterinae). Chitwood (Jour. Wash. Acad. Sci., 1933, 512) placed it under Cylindrogasteridae.

Cephalobidae

Acrobeles sp., found in garden soil, Reedbeds, Adelaide.

Cephalobus cephalatus Cobb, Agr. Gaz. N.S.W., 9, 1901, 115-7, fig. 1, roots of passion fruit, Sackville, New South Wales.

Cephalobus multicinctus Cobb, Agr. Gaz. N.S.W., 4, 1893, 829-30, fig. 44, about roots of sugar cane, Clarence River, New South Wales. Micoletzky, 1921, 272, probable syn. of *C. oxyuroides* Man.

Cephalobus similis Cobb, Macleay Vol., 1893, 288-9, lettuce, Sydney. Micoletzky, 1921, 273.

Cephalobus sp. Heydon and Green, Med. Jour. Austr., 1931, (1), 626, from stale human faeces, North Queensland.

ANGUILLULINIDAE (ANGUINIDAE syn. TYLENCHIDAE)

Anguillulina tritici (Steinb.), more commonly known as *Tylenchus tritici,* q.v., also *T. scandens.* Chitwood (1935) has indicated that *Anguina* Scopoli has priority over *Anguillulina,* but Stiles (Nature, 138, 1936, 34; Zool. Anz., 115, 1936, 110) has suggested that in this case priority should be waived.

Anguillulina dipsaci (Kühn), more commonly known as *Tylenchus devastatrix,* q.v. Millikan, Jour. Agr. Vict., 33, 1935, 563-6, bulbs, Victoria. Filipjev (1934) has assigned the species to *Ditylenchus.* Syn., *Tylenchus dipsaci,* q.v.

Anguillulina radicicola Greef, more commonly known as *Heterodera radicicola* or *Tylenchus rad.,* q.v. Goodey (1932; 1933) has indicated that the specific name should be restricted to the eel-worm known as *Tylenchus hordei,* whereas the species generally called *T. radicicola* should be known as *Heterodera marioni* q.v.

Anguillulina (Fergusobia) tumifaciens Currie, Pr. Linn. Soc., N.S.W., 72, 1937, 158-163, figs. 26-28, pl. 6-7, from Eucalyptus galls, associated with an Agromyzid fly, *Fergusonia carteri,* N.S.W. Type of subgenus. Currie has given an excellent account of the nematode, which passes through a free-living stage, with males and females, in leaf galls of *Eucalyptus Stuartiana* and *E. macrorhyncha* in the vicinity of Canberra. Then there follows a parasitic female generation in the body cavity of the gall flies. Currie also referred to this "symbiotic association between flies and nematodes in galls of eucalypt trees" in Nature, 136, 1935, 263. Unfortunately, the specific name (which should be amended to *tumefaciens)* is pre-occupied in the genus by *A. tumefaciens* (Cobb, 1932) Goodey, 1933, syn. *Tylenchus tumefaciens* Cobb, from galls in the grass, *Cynodon,* in South Africa. Dr. Currie's attention was drawn to this fact, but he has requested the author to undertake renaming, if considered necessary. In recognition of the excellent account of the biology of the species, the latter is here renamed *A. (F.) curriei.*

Anguillulina (Fergusobia) curriei nom. nov. Type of subgenus. See *A. (F.) tumifaciens.*

Aphelenchoides fragariae (Ritzema-Bos), the cause of "cauliflower disease" of strawberry, "red plant," or "strawberry bunch" (Cobb, 1891). Cobb, Agr. Gaz., N.S.W., 2, 1891, 390-400; unnamed nematodes reported as the cause of the disease in New South Wales, the species being described in the same year by Ritzema-Bos as *Aphelenchus fragariae.* Goodey (1933) transferred it to *Aphelenchoides.* The disease occurs in South Australia.

Aphelenchus fragariae. See *Aphelenchoides fragariae.*

Aphelenchus microlaimus Cobb, Agr. Gaz., N.S.W., 2, 1891, 395; Macleay Vol., 1893, 302-3, fig. 10, common in grass, Sydney. Micoletzky, 1921, 588, 590, 591 (synonym of *A. parietinus).*

Aphelenchus spp. Cobb (Jour. Parasit., 8, 1921, 95) referred to the presence of twenty-six species of nematodes, including four new (unnamed) species of *Aphelenchus,* collected from material about the roots of *Kentia* palms.

Aphelenchus sp. Samuel, Jour. Dept. Agr., S. Austr., 32, 1928, 43, wheat and oats, South Australia. See *Heterodera schachtii.*

Entylenchus setiferus (Cobb 1893) Cobb 1913. Originally described by Cobb, Agr. Gaz., N.S.W., 4, 1893, 813, figs. 32-33, as *Tylenchus setiferus,* from soil, Clarence River; transferred by him to *Entylenchus* in 1913 (Jour. Wash. Acad. Sci., 1913, 437). Micoletzky, 1921, 577. Baylis and Daubney (1926) regarded the genus as a synonym of *Anguillulina,* but Micoletzky (1921), Goodey (1933), Filipjev (1934) and Rauther (1930) considered it valid.

Caconema radicicola (Greef). Pittman, Jour. Agr. West. Aust., ser. 2, 6, 1929, 436-46 (many host plants in W.A.). See *Heterodera radicicola.*

Heterodera marioni (Cornu). Goodey (1933) indicated that the eelworm referred to by authors as *H. radicicola* is not Greef's species, but belongs to Cornu's. Pittman, Jour. Agr. West Aust., 14, 1937, 289, potatoes, W.A.

Heterodera radicicola (Greef). See *H. marioni, Caconema radicicola* and *Tylenchus radicicola.* Tryon, Queensl. Agr. Jour., 11, 1902, 406; 13, 1903, 463; banana roots, Cairns; 22, 1909, 100-2, various plant roots, presumably Queensland; also in Ann. Reports Queensland Dept. Agr. Wood, Qld. Agr. Jour., 27, 1911, 38-40, root gall, soil treatment, North Qeensland. Laidlaw, Jour. Agr. Vict., 12, 1914, 370-7, potatoes, onions, Vict.; Harris, Jour. Agr. Vict., 20, 1922, onions, Vict.; Noble, Agr. Gaz. N.S.W., 39, 1928, 546-8, N.S.W.; Manuel, Agr. Gaz. N.S.W., 35, 1924, 581-8, grape roots, N.S.W. Johnston, Rep. Bur. Microbiol., N.S.W., 1909, 57, tomato roots, N.S.W. Darnell-Smith, *ibid.,* 1910-11, 1912, 169, passion vine roots, N.S.W. It occurs on the roots of garden plants in light soils in Adelaide.

Eggs of *Oxyuris incognita* Kofoid have been recorded as found in human excreta in North Queensland. Sandground showed that such eggs belonged to *H. radicicola* ingested along with vegetables. Heydon and Green (Med. Jour. Austr., 1926, (2), 42) referred to these occurrences and reported finding *H. radicicola* in carrots and radishes grown in Townsville.

Heterodera schachtii Schmidt. Spafford, Jour. Agr. S. Aust., 26, 1922-3, 535, cereals, S.A. Davidson, *Ibid.,* 34, 1930, 378-85, cereals, S.A. Hickenbotham, *Ibid.,* 34, 1930, 386-92, "no growth patches" in wheat fields, Roseworthy, S.A. Garrett, *Ibid.,* 37, 1934, 984-7, S.A. Spafford, *Ibid.,* 35, 1932, 836; 39, 1936, 1006, eelworms attacking cereals, S.A. Johnston, W., *Ibid.,* 37, 1934, 705-6, eelworms attacking cereals and grasses, S.A.

Tylenchulus semipenetrans Cobb, Jour. Agr. Res., 2, 1914, 218-30, roots of citrus trees, Gosford, N.S.W. Goodey, 1933, 123, citrus roots, Australia and elsewhere.

Tylenchus arenarius Neale. Cobb. Agr. Gaz., N.S.W., 1, 1890, 121-2, roots, Glen Innes, N.S.W.; 1, 1890, 155-184, figs. 1-8, pl. 4, "root gall" in N.S.W., —p. 166, from Queensland, based on Bancroft's published account of worms attacking roots of grape and banana—p. 166, worm may be *T. (Het.) radicicola* or

T. (H.) javanicus. Cobb, Agr. Gaz. N.S.W., 1901, 1041, identified it as *T.* (or *Heterodera) radic.* q.v.

Tylenchus davainii Bast. Cobb, Agr. Gaz. N.S.W., 1, 1890, 175, Australia.

Tylenchus dihystera Cobb, Agr. Gaz. N.S.W., 4, 1893, 814-5, about roots of sugar-cane, Clarence River. Micoletzky, 1921, 551.

Tylenchus dipsaci Kühn. Noble, Agr. Gaz. N.S.W., 36, 1925, 827, lucerne, Hunter River; *ibid.,* 39, 1928, 548-9, lucerne, N.S.W. Edwards, Agr. Gaz. N.S.W., 43, 1932, 305-14, 345-56, bulbs, lucerne, etc., N.S.W. See *Tylenchus devastatrix, Anguillulina dipsaci.*

Tylenchus devastatrix Kühn. Cobb, Agr. Gaz. N.S.W., 1, 1890, 173, *T. dipsaci* quoted as syn.—"there is reason to believe that [the species] exists also in Australia"; Macleay Vol., 1893, 299-300, fig. 9, no localities mentioned; Agr. Gaz. N.S.W., 4, 1893, 812, fig. 31; *Ibid.,* 13, 1902, 1031-3, "from various parts of Australia," Richmond River, N.S.W.; *Ibid.,* 9, 1898, 425, fig. 86; *Ibid.,* 2, 1891, 678-82, quoted a report by A. N. Pearson (p. 678-9) on the presence of eel-worm in Victorian onion fields, specimens determined by Cobb (p. 679) as *T. devastatrix;* Yearbook U.S. Dept. Agr., 1914 (1915), 485, Australia. Johnston, Pr. Linn. Soc. N.S.W., 34, 1909, 417, N.S.W., Tasmania. Tidswell and Johnston, Agr. Gaz. N.S.W., 20, 1909, 1011-12, N.S.W.; Farmers' Bull., 31, 1909, 22-25 (Dept. Agr. N.S.W.); Rep. Bur. Microbiol. 1909, 62-3. Darnell-Smith, Rep. Bur. Microbiol. N.S.W., for 1910, 1911 (1912), 168, roots grape vine (apparently an error for *T. radicicola).* Laidlaw and Price, Jour. Agr. Vict., 8, 1910, 163-171; onion, Vict. Laidlaw, *ibid.,* 8, 1910, 87-90, 508-11, potato, Vict. Holmes, *ibid.,* 8, 1910, 570-82, potato, Vict. Seymour, *ibid.,* 8, 1910, 360-4, Vict. Editor, *ibid.,* 9, 1911, 845, onions, Vict. Harris, *ibid.,* 20, 1922, 104, onions, Vict. Noble, Agr. Gaz. N.S.W., 39, 1928, 549, daffodils and jonquils, N.S.W. Editor, Jour. Agr. West Austr., 18, 1909, 351, extract from Kirk's N.Z report on *T. devastatrix* in potatoes. Pittman, *ibid.,* ser. 2, 14, 1937, 289, potatoes, W.A. See also *T. dipsaci, Anguillulina dipsaci.*

Tylenchus emarginatus Cobb, Agr. Gaz. N.S.W., 4, 1893, 814, soil, Clarence River. Micoletzky, 1921, 551.

Tylenchus minutus Cobb, Agr. Gaz. N.S.W., 4, 1893, 815, roots of sugar-cane, Clarence River. Micoletzky, 1921, 552.

Tylenchus radicicola Greef (of authors). Cobb, Macleay Vol., 1893, 297-9, gallworm, "a veritable pest in many parts of New South Wales, Queensland and Victoria," also long list of host plants; Agr. Gaz. N.S.W., 8, 1897, 235-244, figs. 48-55, Bundaberg to Adelaide, in all parts of Australia, except Tasmania; *ibid.,* 12, 1901, 1041-52 *(T. arenarius* Cobb 1890 is syn.); *ibid.,* 13, 1902, 1031-33, fig. 1. Magee, Agr. Gaz., N.S.W., 42, 1931, 429, tomato root-gall, N.S.W.; Magee and Morgan, *ibid.,* 43, 1932, 431, tomato eel-worm galls, N.S.W. Editor, Jour. Agr. S. Austr., 1, 1897-8, 142, Port Augusta, S.A. See also *Tylenchus* sp., *Heterodera radicicola, H. marioni* and *Caconema radicicola.*

Tylenchus scandens Schn. Nicholls, Tasm. Jour. Agr., 4, 1933, 104-7, wheat, Tasmania. Syn. of *T. tritici.*

Tylenchus setiferus Cobb, Agr. Gaz. N.S.W., 4, 1893, 813, figs. 32-3, soil, Clarence River. Transferred to *Entylenchus* by Cobb in 1913.

Tylenchus sp. Tryon, Queensl. Agr. Jour., 11, 1902, 406; 13, 1903, 463; Ann. Reports Queensl. Dept. Agr., banana roots, Cairns. Lea, Agr. Gaz. Tasm., 13, 1905, 136; 16, 1908, 15, potato gall-worm, Tasmania. Kirk, Agr. Gaz. Tasm., 17, 1909, 189, potato, no locality, reprint of New Zealand report.

Tylenchus tritici (Steinb.), the cause of ear-cockle of wheat. Crawford, Proc. Roy. Agr. Hort. Soc. South Aust., 1881, 190-11, Koolunga, S.A. Cobb, Agr. Gaz. N.S.W., 1890, 173, referred to its presence in Europe, but was apparently unaware of its recorded occurrence in Australia. Editor, Jour. Agr. S. Aust., 3, 1899, 273, 407, 431-2, 477, wheat, Murray Flats, S.A. Helms, Producers' Gaz., W. Aust., 1898, wheat, W. Aust.; Jour. Agr., W. Aust., 1, 1900, 22-30; 7, 1903, 190-4; 10, 1904, 34, wheat, W. Aust. Carne, Jour. Agr., W. Aust., ser. 2, 3, 1926, 508-11, W. Aust.

Tylenchus uniformis Cobb, Agr. Gaz. N.S.W., 4, 1893, 815-6, soil around roots, sugar-cane, Clarence River. Micoletzky, 1921, 551.

Plectidae

Plectus agilior Cobb, Pr. Linn. Soc. N.S.W., 23, 1898, 398, on grass, Sydney.

Plectus cephalatus Cobb, Agr. Gaz. N.S.W., 4, 1893, 828, fig. 42, from soil, moss roots, Clarence River; Cobb, Agr. Gaz. N.S.W., 9, 1898, 423, fig. 84, no locality. Micoletzky, 1921, 214, 241-2, synonym of *P. (Wilsonema) auriculatus* Bütschli. Baylis and Daubney (1926, 56) quoted *P. cephalatus* as type of *Wilsonema,* apparently an error for *P. capitatus,* a species from the United States.

Plectus insignis Cobb, Macleay Vol., 1893, 38-9, from soil, Moss Vale, N.S.W. Micoletzky, 1921, 217.

Plectus intermedius Cobb, Agr. Gaz. N.S.W., 4, 1893, 827, from soil at roots of sugar-cane, Clarence River. Micoletzky, 1921, 216.

Plectus minimus Cobb, Agr. Gaz. N.S.W., 4, 1893, 826, from soil, Clarence River. Micoletzky, 1921, 217.

Plectus parietinus Bast. Cobb, Macleay Vol., 1893, 256, from celery stalks, Sydney; Agr. Gaz. N.S.W., 4, 1893, 826 (apparently from the Clarence River district); Agr. Gaz. N.S.W., 9, 1898, 436, fig. 93, no locality. Micoletzky (1921, 216, 219, 221) regards it as a variety of *P. cirratus* Bast.

Plectus parietinus var. *australis* Cobb, Pr. Linn. Soc. N.S.W., 23, 1898, 397-8, from grass and celery, Sydney. Micoletzky 1921, 216 (synonym of *P. cirratus* var. *parietinus).*

Plectus pusillus Cobb, Agr. Gaz. N.S.W., 4, 1893, 826-7, from soil around moss roots, Clarence River. Micoletzky, 1921, 216 (probably only a form of *P. cirratus).*

Camacolaimidae

Bastiana (i.e., Bastiania) australis Cobb, Agr. Gaz. N.S.W., 4, 1893, 824, from soil, Clarence River. Micoletzky, 1921, 141 (possibly syn. of *B. longicaudata* Man).

Axonolaimidae

Araeolaimus spectabilis Ditl. Allgen, Zool. Anz. 73, 1927, 197-8, fig. 1, from low tide zone, Derwent River, Tasmania.

Axonolaimus sp. Man, in his account of the free-living nematodes of Zuider-Zee (1922-232), stated that a species of the genus had been described from South Victoria, Australia. He must have confused Cobb's species, *A. polaris* (1914) from Cape Royds, South Victoria Land, collected by Shackleton's Antarctic Expedition. The same species was identified by Cobb (1930) from material obtained by the Australasian Antarctic Expedition from Commonwealth Bay. Coninck and Stekhoven (1933) transferred the species to *Odontophora*.

Comesomatidae

Comesoma heterura Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 386-7, Port Jackson.

Comesoma jubata Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 389-90, Port Jackson.

Comesoma similis Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 387-9, Port Jackson.

Monhysteridae

Monhystera australis Cobb, Agr. Gaz. N.S.W., 4, 1893, 824, from soil, Harwood, Clarence River; nec *M. australis* Cobb, Proc. Linn. Soc. N.S.W., 18, 1893 (1894). 408-9, marine, Port Jackson. According to Steiner (Zool. Anz., 47, 1916, 63) and Micoletzky (1921, 170, 181) the former is a synonym of *M. villosa* Bütschli. The latter is renamed in the present paper as *M. pacifica*.

Monhystera brevicollis Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 403-4, Port Jackson.

Monhystera diplops Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 401-3, fig. 8, Port Jackson. Agr. Gaz. N.S.W., 1898, 318, fig. 40, no locality. Micoletzky (1921, 169), who did not know of the original account, stated that Cobb's 1898 figure of *M. diplops* indicated the species to be a synonym of *M. stagnalis* Bast. Cobb's early account (1893) relates to a marine species, but in 1904 (Proc. Cambridge Philos. Soc., 12, 1904, 366) he recorded a species under the same name from fresh water in New Zealand.

Monhystera filiformis Bast. See *M. rustica*.

Monhystera gracillima Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 406-8, Port Jackson; nec *M. gracillime* Man, Capita Zool., 1 (1), 1921, 5-6, from soil in Holland; nec *M. gracillima* Kreis, Capita Zool., 2 (7), 1929, 63-4, marine, from the north-west coast of France. Man's species is here renamed *M. gracilior*, and Kreis' species as *M. kreisi*.

Monhystera insignis Cobb, Agr. Gaz. N.S.W., 4, 1893, 823, from soil around roots of sugar-cane, Harwood, Clarence River. Micoletzky, 1921, 172.

Monhystera lata Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 404-5, Port Jackson.

Monhystera pacifica, nom. nov. for *M. australis* Cobb, 1893 (1894), 408, nec Cobb, Agr. Gaz. N.S.W., 4, 1893, 824. See *M. australis.*

Monhystera pratensis Cobb, Agr. Gaz. N.S.W., 4, 1893, 823-4, from soil about roots of sugar-cane. Harwood, Clarence River. Micoletzky, 1921, 172.

Monhystera rustica Bütschli. Cobb, Agr. Gaz. N.S.W., 4, 1893, 822-3, fig. 40, from moss roots, Clarence River; Macleay Vol., 1893, 279-80, pl. 37, from "many parts of Australia." Micoletzky (1921, 178) placed the species as a synonym of *M. filiformis* Bastian.

Monhystera setosissima Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 405-6, Port Jackson. The name was mis-spelt as *sesotissima* by Micoletzky (Kgl. Dansk. Vid. Selsk. Skr., 10 (2), 1925, 228).

Monhystera tasmaniensis Allgen, Zool. Anz., 73, 1927, 198-200, fig. 2, Tasmania.

Monhystera villosa Bütschli. See *M. australis.*

SIPHONOLAIMIDAE

Chromagaster purpurea Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 417-9, fig. 12, North Arm, Port Adelaide. In a footnote to the same paper (p. 419) Cobb stated that the genus (which he had just erected) would probably have to be united with *Siphonolaimus.* Cobb, Agr. Gaz. N.S.W., 1898, 318, fig. 41 (no locality given). Steiner (1921), Allgen (1930), Rauther (1930), and Filipjev (1934) regarded the genus as a synonym of *Siphonolaimus.* It may be mentioned that Allgen in 1932 and 1933 described new species from Norway and Sweden, apparently regarding the genus as valid.

Siphonolaimus purpureus (Cobb, 1893) Allgen, 1930; see *Chromagaster purpurea.*

LINHOMOEIDAE

Cryptolaimus pellucidus Cobb, Jour. Parasit., 20, 1933, 86, from mud, North Arm, Port Adelaide.

Siphonolaimus purpureus (Cobb, 1893) Allgen, 1930; see *Chromagaster* Port Jackson.

Terschellingia exilis Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 392-3, Port Jackson.

CHROMADORIDAE[1]

Chromadora conicaudata Allgen, Zool. Anz., 73, 1927, 208-10, fig. 6, Tasmania.

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[1] In 1930 Cobb described *Chromadora dubia* from marine material collected by the Australasian Antarctic Expedition. The specific name is pre-occupied by *C. dubia* Bütschli, 1873. The name *C. cobbiana* is now proposed for the former.

Chromadora macrolaima Man. Allgen, Zool. Anz., 73, 1927, 204, Tasmania. See *Chromadorina macrolaima.*

Chromadora macrolaimoides Steiner. Allgen, Zool. Anz., 73, 1927, 204-7, fig. 5, Tasmania.

Chromadora microlaima Man. Allgen, Zool. Anz., 73, 1927, 208, Tasmania. See *Chromadorina microlaima.*

Chromadora minima Cobb, Agr. Gaz. N.S.W., 4, 1893, 820-1, fig. 38, from soil around roots of sugar-cane, Harwood, Clarence River, and from Moss Vale, New South Wales. Micoletzky, 1921, 378 (= *Cyatholaimus minimus).* Cobb, (Jour. Wash. Acad. Sci., 1913, 441) made the species the genotype of *Achromadora* q.v. (under Cyatholaimidae).

Chromadora minor Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 394-9, fig. 6, Port Jackson. Cobb, Agr. Gaz. N.S.W., 1898, 299, fig. 9 (no locality).

Chromadora wallini Allgen, Zool. Anz., 73, 1927, 210-12, fig. 7, Tasmania.

Chromadorina macrolaima (Man) Coninck and Stekhoven, 1933, syn. *Chromadora macrolaima,* q.v.

Graphonema vulgaris Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 406-7, coast of New South Wales and Victoria. The genus has been regarded as a synonym of *Chromadora,* but Filipjev (1934) listed it as valid. Cobb (1935) has stated that it is a synonym of *Euchromadora,* hence its genotype, *G. vulgaris,* becomes *E. vulgaris* (Cobb).

Graphonema pachyderma Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 406. Nomen nudum. Cobb stated that the species would be described later, but apparently did not do so. Some features contrasting it with *G. vulgaris* were mentioned. No locality was given, but was presumably Australian.

Euchromadora vulgaris (Cobb, 1898). Syn. *Graphonema vulgaris,* q.v.

Euchromadora pachyderma (Cobb, 1898). Syn. *Graphonema pachyderma,* q.v.

Hypodontolaimus minor Allgen, Zool. Anz., 73, 1927, 212-14, fig. 8, Tasmania.

Spilophora (or *Spiliphera) loricata* Steiner. Allgen, Zool. Anz., 73, 1927, 200-2, fig. 3, Tasmania.

Spilophorella tasmaniensis Allgen, Zool. Anz., 73, 1927, 202-3, fig. 4, Tasmania.

CYATHOLAIMIDAE

Achromadora minima (Cobb, 1893) Cobb, 1913. Syn. *Chromadora minima,* q.v. Cobb (1933) and Filipjev (1934) placed the genus in Cyatholaiminae. Micoletzky (1921, 378) considered the genus to be a synonym of *Cyatholaimus* in 1921, but later (1925) placed Cobb's species as a synonym of *A. ruricola* (Man).

Achromadora ruricola (Man). See *A. minima.*

Cyatholaimus brevicollis Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 403-4, Port Jackson.

Cyatholaimus exilis Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 400, Port Jackson.

Cyatholaimus heterurus Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 400-2, Port Jackson.

Cyatholaimus minimus (Cobb) Micoletzky. See *Achromadora minima.*

Cyatholaimus minor Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 402-3, Port Jackson.

Cyatholaimus proximus Bütschli. Allgen, Zool. Anz., 73, 1927, 214-5, fig. 9, Tasmania. Genus quoted, in error, as *Cyatholaismus.*

Cyatholaimus trichurus Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 398-400, Port Jackson.

Halichoanolaimus australis Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 404-6, Port Jackson.

Neonchus longicauda Cobb, Agr. Gaz. N.S.W., 4, 1893, 819-20, fig. 37, from soil at roots of sugar-cane, Harwood, and at roots of moss, Maclean, Clarence River. Genotype. Micoletzky (1921, 419) and Cobb (1935) placed the genus as a synonym of *Odontolaimus,* the former (p. 420) regarding the species as *O. chlorurus* Man.

Odontolaimus chlorurus Man. Syn. *Neonchus longicauda,* q.v.

Tripyloididae

Bathylaimus australis Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 409-10, Port Jackson; Agr. Gaz. N.S.W., 9, 1898, 432, fig. 91, no locality.

Desmodoridae

Laxus longus Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 415-6, fig. 11, Port Jackson.

Spira similis Cobb, Proc. Linn. Soc. N.S.W., 18, 1893, 390-2, Port Jackson. Perhaps the same as *S. parasitifera* Bast. See *Spirina similis.*

Spirina similis (Cobb, 1898); syn., *Spira similis,* q.v.

Epsilonematidae

In 1926 Steiner erected *Epsilonema* to replace *Rhabdogaster* Metchnikoff (pre-occupied), basing its characters on a species which he believed to be the genotype, *R. cygnoides.* Baylis and Daubney (1926) had, a few months previously, proposed *Prochaetosoma* for it. Steiner (1931) recognised the latter as valid, gave a diagnosis, and named *P. holocricum* Steiner, 1931 (an Antarctic species which was not an original member of the genus) as type. He reported that the diagnosis given in 1926 was based on a species distinct from Metchnikoff's and that, consequently, he retained Epsilonematidae rather than Prochaetosomatidae as the family name. In addition to *P. cygnoides,* he referred to many new species or varieties found in Antarctic and Subantarctic waters by the "Gauss" Expedition (1931, 312, 316-7, etc.). *Ep. cyrtum* Steiner, which was not an original species, was named as type.

Steiner (1931) indicated in his key, as also did Cobb (1935), that *Prochaetosoma* and *Epsilonema* Steiner, 1931, were not congeneric because of differences in the structure of the cuticular annulations. Numerous species or varieties were described as belonging to the latter genus. Chitwood (Proc. Helm. Soc., Wash., 2, 1935, 54) designated *Ep. steineri*, a new name proposed for *Rhabdogaster cygnoides* Steiner nec Metchnikoff, as type of *Epsilonema* Steiner.

From the foregoing it is obvious that Steiner's generic name has been applied to two different groups. In the first place it was a renaming of *Rhabdogaster* (Steiner, Jour. Parasit., 14, 1927, 65), as also was *Prochaetosoma* B. and D., the type of this group being *R. cygnoides* Metchnikoff. Then, later, the name was deliberately retained for an allied group, including *R. cygnoides* Steiner nec Metchnikoff, renamed *Ep. steineri* by Chitwood. The second group is admittedly not congeneric with the former and should be renamed. *Epsilonematina* is now proposed for it, with *Ep. steineri* (Chitwood) as its type, all the species described by Steiner in 1931 as belonging to *Epsilonema* being included under it. As *Prochaetosoma* B. and D., 1926, is pre-occupied, the name having been used by Micoletzky (1921, 416), *Epsilonema* Steiner, 1926, remains as the valid generic names for the species included by Steiner (1931) under *Prochaetosoma* B. and D.[2]

Epsilonematina spp. Species occur in the littoral zone near Adelaide and Port Willunga (South Australia); Portland and Port Phillip (Victoria); Derwent River (Tasmania); Port Jackson, Broken Bay and Long Reef (New South Wales).

DREPANONEMATIDAE nom nov.

The new name, Drepanonematidae, is given to the group of nematodes to which the following terms have been applied:—Chaetosomatiden by Schepotieff 1908; Chaetosomidae by Southern 1914, Chaetosomatidae by Steiner 1916, Micoletzky 1921, Baylis and Daubney 1926, Allgen 1932, and by later authors generally; Chaetosomatinae by Rauther 1930; Draconematidae by Cobb 1929, Steiner 1931,

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[2] Under *Epsilonematina* would be included the following species and varieties described under *Epsilonema* by Steiner:—*Epsilonematina ateles, allohystera, antarctica, aphana, brachycraspedota, colobathrophora, cyclophora, cyrta, camptocrica, campta, corynodes, dictyotocrica, dichotoma, dicrocrica, desmocrica, eucraspedota, frigida, homalocrica, herpeta, homoicrica, hexastoicha, heterocrica, ilyspastica, leptothorax, leptomeres, leptotricha, metchnikoffi, mixta, nanna, oligechon, oligoschista, poicilothrix* and its varieties *strongylota* and *macra, primitiva, polycrica, philopsychra, pneumatica, rhogmacrica, rhabdota, simoloma, signatoides, sphalera, symbiotica, semeionoides, trachelogaster, thinophila, trachelota, thyridocrica* and *tricola*, as well as *steineri* (Chitwood).

Under *Epsilonema* should be included the following species and varieties described by Steiner under *Prochaetosoma*:—*Ep. apionipherum, aschistocricum, atechnum* with varieties *heterocrica* and *lophocrica, cosmetocricum, charactocricum, docidocricum, dynatocricum, eumecum, eucalobates, eustegum, geometroides, glaphyrum, glottocricum, hygrum, holocricum, hadrocteum* with varieties *asymmetrica* and *epsilonoides, leptotrachelum, labidurum, monadicum* and varieties *conocephala, microctenum, oligistocricum, oligostegum, placipherum, polyschistum, penionoides, pachymerum, sphenostegum, striatum, stenocricum, sterrurum, stolidotum, tenue* and *tegocricum*, as well as *cygnoides* (Metchnikoff nec Steiner).

Allgen 1932, Schuurmans-Stekhoven 1935, and by Chitwood and Chitwood 1937; and Draconematinae by Filipjev 1934. The correct name is, of course, linked with that of the type genus, originally *Chaetosoma* Claparède, 1863 (preoccupied). *Tristicochaeta* Panceri, 1878, is commonly regarded as a synonym, and if so, would be the valid name, but Southern (1914) pointed out that they were distinct. Irwin-Smith (1917) grouped the two under the former name. In 1913 Cobb erected *Draconema*. Micoletzky (1921, 416) listed the latter as a synonym of *Chaetosoma*, considered *Notochaetosoma* Irwin-Smith as valid, and proposed *Prochaetosoma*, with *P. primitivum* (Steiner) as type, as an additional genus in the Chaetosomatidae. In 1929 Cobb regarded *Draconema* as distinct from *Chaetosoma* and stated that the latter name should be replaced by *Notochaetosoma*, which he regarded as synonymous, and that if the family be considered as containing only one genus, then the name of the latter would be *Draconema*, family Draconematidae. In 1933 Cobb proposed *Drepanonema* to replace Claparède's name, the Zoological Record incorrectly quoting the date as 1922. In 1926 Baylis and Daubney (1926) regarded *Tristicochaeta* and perhaps *Draconema*, as synonymous with *Chaetosoma*. Rauther in 1930 considered *Draconema* a synonym. In 1934 Filipjev erected *Claparediella* to replace *Chaetosoma*, and referred to the differences between *Draconema* and *Notochaetosoma*. In 1935 Cobb quoted *Draconema* as synonymous with *Tristicochaeta*, and listed *Notochaetosoma* as valid. Schuurmans-Stekhoven (1935, 100) considered Filipjev's name to be the correct one, and placed *Chaetosoma tristichochaeta* Panceri under *Draconema* (p. 101).

From the foregoing discussion it will be seen that the correct name for *Chaetosoma* is *Drepanonema* Cobb, with *Claparediella* as a synonym, and that the family should be known as Drepanonematidae nom. nov. (or Drepanonematinae, if only subfamily rank be accorded).

Chaetosoma falcatum Irwin-Smith, Proc. Linn. Soc. N.S.W., 42, 1917 (1918), 766-782, figs. 1-24, pls. 44-45, Port Jackson. See *Tristicochaeta falcata*.

Chaetosoma haswelli Irwin-Smith, Proc. Linn. Soc. N.S.W., 42, 1917 (1918), 782-798, figs. 25-47, pls. 46 47, Port Jackson and Broken Bay, New South Wales. Cobb (Jour. Wash. Acad. Sci., 19, 1929, 260; Contrib. Sci. Nematol., 22, 1929 418) regarded the species as a synonym of *Draconema cephalatum*. See *Tristicochaeta haswelli*.

Tristicochaeta falcata (Irwin Smith). Syn. *Chaetosoma falcatum*, q.v.

Tristicochaeta haswelli (Irwin-Smith). Syn. *Chaetosoma haswelli*, q.v.

Notochaetosoma cryptocephalum Irwin-Smith, Proc. Linn. Soc. N.S.W., 42, 1917 (1918), 808-811, figs. 57-9, pl. 50, Port Jackson.

Notochaetosoma tenax Irwin-Smith, Proc. Linn. Soc. N.S.W., 42, 1917 (1918), 798-808, figs. 48-56, pls. 47-49, Port Jackson.

Drepanonema spp. Drepanonematids occur in the littoral zone at Marino and Port Willunga, South Australia; Portland and Port Phillip, Victoria; Derwent River, Tasmania.

Desmoscolecidae

Desmoscolex spp. occur in the marine littoral zone in South Australia, Victoria, New South Wales and Tasmania.

Tricoma sp. occurs sparingly in the marine littoral zone in South Australia, Victoria, New South Wales and Tasmania.

Greeffiellidae

Greeffiella sp. occurs very sparingly in the marine littoral zone in South Australia, Victoria, New South Wales and Tasmania.

Enoplidae

Anticoma lata Cobb, Proc. Linn. Soc., N.S.W., 23, 1898, 384-5, Port Jackson.

Anticoma similis Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 383-4, Port Jackson.

Anticoma trichura Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 385-6, Port Jackson.

Leptosomatum australe Linstow, 1905. Stiles and Hassall (Index Cat. Med. Vet. Zool. Roundworms, 1920, 564) stated, in error, that Linstow in 1907 had recorded the presence of the species at Hut Point, Australia. The locality is in South Victoria Land, Antarctica (Linstow, Nematoda, Nat. Antarctic Exp. Nat. Hist., 3, Zool. Bot., 1907).

Oxystoma pellucida Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 395-7, Port Jackson. Man (1907) stated that it was probably a synonym of *O. elongata* Bütschli. See *Oxystomina pellucida*.

Oxystomina pellucida (Cobb). Syn., *Oxystoma pellucida*, q.v.

Oncholaimidae

Enchelidium sp. Cobb, Misc. Publ. No. 215, Dept. Agr. N.S.W., 1898, 22, fig. 40; no locality. The figure does not appear in the original paper in Agr. Gaz. N.S.W., 1898. The reference may not be to an Australian species.

Monocholaimus elegans Kreis var. *tasmaniensis* Allgen, Zool. Anz., 73, 1927, 215-6, fig. 10, Tasmania. Kreis (Cap. Zool., 4, (5), 139-41, fig. 81) regards it as a species, *M. tasmaniensis*.

Mononcholaimus tasmaniensis Allgen. Syn. *M. elegans* var. *tasmaniensis*.

Oncholaimus pellucidus Cobb, Proc. Linn. Soc. N.S.W., 23, 1898, 394-5, Port Jackson. Kreis (Cap. Zool., 4, (5), 1934, 168, 169) to *Viscosia*.

Oncholaimus viridis Bast. Allgen, Zool. Anz., 73, 1927, 216, fig. 11, Tasmania.

Symplocostoma longicolle Bast. Allgen, Zool. Anz., 73, 1927, 217, Tasmania.

Viscosia pellucida (Cobb) Kreis. Syn., *Oncholaimus pellucidus*, q.v.

Ironidae

Cephalonema longicauda Cobb, Agr. Gaz. N.S.W., 4, 1893, 825, fig. 41, from soil around roots of sugar-cane, Clarence River. Genotype, generic name pre-occupied and replaced by *Nanonema* Cobb, 1905 (in Stiles and Hassall, Bull. 79, U.S.D.A., B.A.I., 1905, 122). Micoletzky (1921, 323) placed *Cephalonema* as a synonym of *Ironus.*

Cephalonema sp. Cobb, Agr. Gaz. N.S.W., 4, 1893, 825, Moss Vale, New South Wales, not described.

Nanonema longicauda (Cobb, 1893) Cobb, 1905. Syn., *Cephalonema longicauda,* q.v. Micoletzky (1921, 325) stated it was a synonym of *I. ignavus* Bast.

Ironus longicauda (Cobb, 1893). Syn., *Nanonema longicauda,* q.v.

Ironus ignavus Bast. See *Nanonema longicauda.*

Trilobidae

Tripyla tenuicauda Cobb, Macleay Vol., 1893, 285-6, from "mud of a brook, Sydney." Micoletzky (1921, 150) called it *T. tenuicaudata* Cobb.

Prismatolaimus australis, Cobb, Macleay Vol., 1893, 287, about roots, Moss Vale, New South Wales. Micoletzky (1921, 197, 198) regarded it as a synonym of *P. dolichurus* Man.

Mononchidae

Mononchus intermedius Cobb, Agr. Gaz. N.S.W., 4, 1893, 817-8, about roots of sugar-cane, Clarence River. Micoletzky, 1921, 341.

Mononchus longicaudatus Cobb, Macleay Vol., 1893, 256, 261, fig. 2, from celery stalks, Sydney; Agr. Gaz. N.S.W., 4, 1893, 818, fig. 36. Micoletzky (1921, 355) stated that it was a synonym of *M. macrostoma.*

Mononchus macrostoma Bast. See *M. longicaudatus.*

Mononchus major Cobb, Macleay Vol., 1893, 260-1, damp soil, Moss Vale; Agr. Gaz. N.S.W., 9, 1898, 319, fig. 44, no locality given. Micoletzky, 1921, 341.

Mononchus similis Cobb, Agr. Gaz. N.S.W., 4, 1893, 818-9, about roots of sugar-cane, Clarence River. Transferred to subgenus *Iotonchus* by Micoletzky, 1921, 343—Not *M. (M.) similis* Cobb, 1917, renamed *M. cobbi* by Micoletzky, 1921, 344.

Mononchus sp. Cobb, Macleay Vol., 1893, 256, from celery stalks, Sydney.

Mononchus sp. Tidswell and Johnston, Rep. Bur. Microbiol., N.S.W., 1, 1909, 71, in diseased bananas, New South Wales.

Alaimidae

Alaimus minor Cobb, Agr. Gaz. N.S.W., 4, 1893, 824, soil, Clarence River. Micoletzky (1921, 136) regards it as a synonym of *A. primitivus* Man.

Alaimus tasmaniensis Allgen, Nyt. Mag., Oslo, 67, 1929, 212-4, fig. 1, from moss, Tasmania.

Dorylaimidae

Dorylaimus bastiani Bütschli. Cobb, Agr. Gaz. N.S.W., 9, 1898, 427, fig. 88; no locality. Steiner, Zool. Anz., 46, 1916, 326-7, fig. 7, from moss roots, Boorabin, South-western Australia. Micoletzky (1921, 446, 449, 468) regarded it as a variety of *D. filiformis* Bast., and considered (p. 475-6) Steiner's form from Western Australia to belong to a distinct variety which he named *steineri.* The latter invalidates the name *D. steineri* Thorne and Swanger (1936, 116), which is here renamed *D. steinerianus* nom nov. Thorne and Swanger (p. 65) included Steiner's figures of the Australian nematode under *D. bastiani.*

Dorylaimus gracilis Man. Steiner, Zool. Anz., 46, 1916, 326, fig. 6, from moss roots, Bridgetown, South-western Australia.

Dorylaimus latus Cobb, Proc. Linn. Soc. N.S.W., 16, 1891, 150-1, from grass roots, Sydney. Micoletzky, 1921, 451, probable synonym of *D. carteri* var. *brevicaudata* forma *minuta.* Thorne and Swanger, 1936, 110-111, pl. 25, fig. 148.

Dorylaimus minimus Steiner, Arch. Hydrobiol. u. Planktonk., 1914, 437-8, renaming of *D. minutus* Cobb nec Bütschli. Thorne and Swanger, 1936, 117, pl. 27, fig. 158.

Dorylaimus minutus Cobb, Agr. Gaz. N.S.W., 4, 1893, 810, around roots of sugar-cane, Clarence River. Name pre-occupied by *D. minutus* Bütschli, 1873, and renamed *D. minimus* by Steiner, 1914.

Dorylaimus pusillus Cobb, Agr. Gaz. N.S.W., 4, 1893, 810-11, around roots of sugar-cane and moss, Clarence River. Micoletzky, 1921, 446, 459, syn. of *D. longicaudatus* Bütschli. Thorne and Swanger (1936, 39) regard it as a valid species (pl. 5, fig. 24).

Dorylaimus spiralis Cobb, Macleay Vol., 1893, 293-4, from base of carrot leaves, Sydney. Micoletzky, 1921, 453, 519-20. Thorne and Swanger, 1936, 125-6, transferred to *Aporcelaimus; D. spiralis* Cobb of Micoletzky, 1921, regarded as a different species and renamed *D. paraspiralis.*

Dorylaimus subsimilis Cobb, Agr. Gaz. N.S.W., 4, 1893, 810, about roots of sugar-cane, Clarence River. Micoletzky, 1921, 455. Thorne and Swanger, 1936, 120.

Dorylaimus spp. Cobb, Macleay Vol., 1893, 256, from celery stalks, Sydney.

Aporcelaimus spiralis (Cobb) Thorne and Swanger, 1936, 125-6, pl. 28, fig. 169. Syn., *Dorylaimus spiralis,* q.v.

Brachynema obtusum Cobb, Agr. Gaz. N.S.W., 4, 1893, 811, from soil, Clarence River. Genotype, generic name pre-occupied, renamed *Brachynemella* by Cobb, Jour. Parasit., 20, 1933, 81. Micoletzky (1921, 131) stated that it was probably related to *Tylencholaimus.*

Brachynemella obtusa (Cobb, 1893) Cobb, 1933. Syn., *Brachynema obtusum,* q.v. Filipjev (1934) regarded the genus as a synonym of *Tylencholaimus,* but Cobb (1935) and Thorne (1935) considered it valid.

Diphtherophoridae

Chaolaimus pellucidus Cobb, Agr. Gaz. N.S.W., 4, 1893, 821, fig. 39, about roots of sugar-cane, Clarence River. Genotype. Micoletzky (1921, 421), Baylis and Daubney (1926) and Filipjev (1934) stated that the genus was a synonym of *Diphtherophora,* the first-named author (p. 422) listing the species as *D. communis* Man. Cobb (1935) accepted the generic synonymy.

Diphtherophora pellucida (Cobb). Probably syn. of *D. communis* Man.

Mermitidae

Australian members of this family have not been studied. The adults are free-living, and the young stages parasitic. Wheeler (Psyche, 40, 1932, 20-32) referred to *Mermis* parasitism in some Australian ants. I have seen adults of *Mermis* sp. collected from a claypan in the Bordertown district of South Australia.

Miscellaneous Remarks

Cobb (Agr. Gaz. N.S.W., 1898, 421, fig. 65) illustrated the anterior end of a nematode, apparently a free-living form, "*Labyrinthostoma* n. gen.," but gave no description, nor did he mention any species or locality. It must be regarded as a nomen nudum. The figure suggests an *Enoplolaimus* near *E. caput-medusae.*

In the same publication Cobb (p. 320, fig. 45) figured *Streptogaster papillatus* n. gen., n. sp. without any information regarding habit or locality. Baylis and Daubney (1926) quoted the habitat as "not mentioned (presumably free-living)" and placed the genus in an appendix to Rhabditidae. Travassos (1919) allotted it to Hystrignathinae. Artigas stated that the species was based on the male of *Heth* and was, therefore, a synonym of the latter. If this be correct, *Streptogaster* must be a parasite of a millipede, and since Cobb in the same article (1898, 299, fig. 10) figured *Heth juli* (female) from *Julus* sp., from Moss Vale, New South Wales, *S. papillatus* probably came from that locality and perhaps from the same host species. Artigas and Travassos (1929) both placed the genus in Ransomneminae (Atractidae), as also did Filipjev (1934). Cobb (1935) did not mention the genus in his key to the genera of free-living nematodes. The species can be placed definitely amongst the parasitic forms.

Gordiacea

The Nematomorpha may be referred to in this paper, though they are not true nematodes. Only a few species have been described from Australia. The group is represented in all Australian States. Though some of the following references relate to the parasitic stage, they are included, since the worms pass through a free-living adult phase. No attempt has been made to allocate species to their proper genera or families.

Chordodes undulatus Linstow, Arch. Naturg., 1906, (1), 257-8, fig. 20, from *Mantis* sp., Sydney.

Chordodes caledoniensis Villot, 1874, from *Mantis*, New Caledonia, was stated by Camerano (1897) to have been taken in New Caledonia, "New Olanda," the latter being a misplaced locality.

Gordius incertus Villot, 1874, Tasmania. Camerano, 1886; 1897.

Gordius flavus Linstow, Mitt. Zool. Mus., Berlin, 3, 1906, 243, fig. 1, from New Britain and (?) Adelaide.

Gordius tuberculatus Villot, 1874, from Rockhampton, "New Holland."

Gordius spp. Whitelegge, Proc. Roy. Soc. N.S.W., 23, 1889, 307, swamps, Botany, New South Wales; Bailey, Vict. Nat., 1, 1884, 2, from *Carabus* (presumably from Victoria); Cobb, Agr. Gaz. N.S.W., 2, 1891, 213-4, Glen Innes, New South Wales; Tryon, Ann. Rep. Dept. Agr. Queensland, 1910-11, 73, Eudlo, Beaudesert and Rockhampton, Queensland; Froggatt, Proc. Linn. Soc. N.S.W., 1909, 216, from stomach of trout, along with larva of a water-beetle, Cooma, New South Wales.

Parachordodes annulatus Linstow, Mitt. Mus. Berlin, 1906, 246, Queensland.

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AUGEN-GNEISSES IN THE HUMBUG SCRUB AREA, SOUTH AUSTRALIA

BY A. R. ALDERMAN

Summary

The interesting occurrence of a large area of augen-gneiss in the neighbourhood of the Humbug Scrub has been noted by a number of writers, particularly Brown and Woodward (1885). Howchin (1905 and 1925 1 , Benson (1909) and Hossfeld (1935). These gneisses constitute an important part of the Older Pre- Cambrian (Barossian) rocks of the Mount Lofty Ranges in this area.

AUGEN-GNEISSES IN THE HUMBUG SCRUB AREA, SOUTH AUSTRALIA

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[Read 9 June 1938]

Plates VIII and IX

Contents

I Introduction

The interesting occurrence of a large area of augen-gneiss in the neighbourhood of the Humbug Scrub has been noted by a number of writers, particularly Brown and Woodward (1885), Howchin (1906 and 1925), Benson (1909) and Hossfeld (1935). These gneisses constitute an important part of the Older Pre-Cambrian (Barossian) rocks of the Mount Lofty Ranges in this area.

Howchin (1906, 258) has shown that the adjacent metamorphosed pelitic sediments pass gradually through a stage of pegmatitic impregnation into the typical augen-gneiss. He suggests, therefore, that the augen-gneisses have been derived from the injection of pegmatite along the cleavage planes of the slaty sediments. Hossfeld (1935, 24-25), on the other hand, although agreeing with the field observations of Howchin, "believes that the augen-gneisses may represent an altered igneous intrusion, changed partly while still in the plastic condition," and cites a contact between augen-gneiss and the surrounding injected schists in Section 3,279, Hundred of Para Wirra.

Over a large part of the area in which the augen-gneisses occur the Barossian rocks are obscured by overlying Tertiary gravels and drift, and the few exposures consist of rock much altered by weathering. The gorge of the South Para River, however, gives an excellent section through the northern extremity of the Humbug Scrub region, and the present writer's observations are based largely on this section.

Some years ago the writer, in the course of making chemical analyses of a number of South Australian rocks, analysed a specimen of a typical augen-gneiss (S.P. 1) from the bed of the South Para River near Section 3,779, Hundred of Para Wirra. This analysis gave grounds for suspecting that the rock was not of purely igneous origin. The analysis is shown in Table A, column i, where its composition may be compared with those of typical igneous rocks of this region.

It will be seen that the augen-gneiss bears no very close chemical resemblance to any of the analyses quoted. Analyses ii and iii in Table A are typical of the great majority of granites [1] from this part of South Australia. It will be noted that the K_2O and Na_2O are approximately equal. One of the rare exceptions to this is shown by analysis iv, in which K_2O exceeds Na_2O by 2%. This analysis has some resemblance to that of the augen-gneiss, but the similarity is not a close one. Analysis v is representative of the dioritic rocks of Houghton type which W. N. Benson (1909) and H. N. England (1935) have shown to be of widespread occurrence in the Mount Lofty Ranges.

Considered alone the chemistry of the South Para augen-gneiss shows no convincing signs that it may be in part of sedimentary origin, although the presence of nearly 5% of corundum in the norm and the considerable excess (3·4%) of K_2O over Na_2O may give some slight suggestion of this. However, the composition of this rock, as will be shown later, is perfectly typical of many undoubted injection gneisses. It has been shown by the field work of Howchin (1906, 258), of Benson (1909, 108), and of Hossfeld (1935, 24), and by the present writer's own observations that the augen-gneisses pass outwards through a region of banded-gneisses and pegmatized schists into pelitic schists which have undergone a varying amount of pegmatitic injection. The field evidence seems to support very strongly the idea that the augen-gneisses are the result of a period of intense injection-metamorphism followed by a period in which the metamorphism was of dynamic type. The main object of this paper is to consider the chemical and mineralogical changes involved in these processes.

II Augen gneisses and Injection-gneisses

The occurrence and limits of the augen-gneisses along the South Para section have been very well shown by Hossfeld (1935, 23), whose map shows the South Para River cutting through the northern extremities of the Humbug Scrub gneisses. The augen-gneisses, which lie within the fringing zones of banded injection-gneisses and pegmatized schists are of extraordinarily constant composition. This constancy of chemical composition is illustrated in Table B. The three rocks whose analyses are given in columns i, ii and iii in that table were collected at well-spaced intervals along the South Para section.

A typical hand-specimen of the augen-gneiss has "augen" of light grey or pale pink felspar and quartz in a fine dark grey micaceous groundmass. The quartz may be colourless or slightly blue. The felspar and quartz have obviously been subjected to extreme granulation. The average size of the prominent felspar-quartz augen is about $2\frac{1}{2}$ x $\frac{3}{4}$ cm., although a few are much larger than this figure indicates. Occasionally the augen are so drawn out that the rock consists of light-

[1] These rocks should more strictly be referred to as adamellites

coloured strings of felspar-quartz separated by darker bands of the fine micaceous material. Such a rock may be referred to as a "banded augen-gneiss."

Under the microscope the augen are seen to consist of strained quartz and felspar, generally microcline or microperthite (pl. ix, fig. 5). These are the dominant minerals of this group of rocks. Acid plagioclase, which usually has the composition of oligoclase, is generally present but in subordinate amount and myrmekite is sometimes developed in the potash felspar. The edges of both the

TABLE A

	i	ii	iii	iv	v
SiO_2	66·89	77·05	73·96	70·77	59·93
TiO_2	0·80	0·36	0·37	0·72	0·79
Al_2O_3	14·96	12·24	13·67	13·69	14·07
Fe_2O_3	2·53	0·47	1·22	1·97	0·75
FeO	1·73	0·54	1·03	0·97	2·87
MnO	0·01	0·06	0·04	0·28	0·06
MgO	1·57	0·10	0·56	0·34	5·02
CaO	1·59	0·20	1·58	0·94	11·77
Na_2O	2·13	4·24	3·01	3·70	3·72
K_2O	5·54	4·86	3·36	5·68	0·36
P_2O_5	0·17	0·02	0·16	0·11	0·76
H_2O + ...	1·23	0·21	0·29	0·45	0·15
H_2O –	0·22	0·10	0·04	0·36	0·06
CO_2	0·89	n.d.	0·22	—	n.d.
ZrO_2	nil	0·10	—	tr.	n.d.
Etc.	—	0·01	0·27	0·17	—
	100·26	100·56	99·78	100·15	100·33
Norms					
Quartz	30·36	33·30	39·72	25·32	11·76
Orthoclase	32·80	28·91	20·02	33·36	2·22
Albite	17·82	35·63	25·15	31·44	31·44
Anorthite	1·67	—	7·23	3·89	20·57
Corundum	4·90	—	2·45	—	—
Diopside	—	0·89	—	—	26·34
Hypersthene	3·90	—	1·53	0·90	3·49
Magnetite	3·25	0·70	1·86	2·09	1·16
Haematite	0·32	—	—	0·48	—
Ilmenite	1·52	0·76	0·76	1·37	1·52
Pyrite	—	—	0·25	0·17	—
Apatite	0·34	0·03	0·34	0·34	1·68
Calcite	2·00	—	0·50	—	—

i Augen-gneiss (S.P. 1), South Para River Anal. A. R. Alderman
ii Granite, Tanunda Creek P. S. Hossfeld (1925, 195)
iii Granite, Palmer Anal. W. S. Chapman R. L. Jack (1923, 68)
iv Granite, Mannum B. F. Goode (1927, 127)
v Diorite, Sect. 257, Hundred of Barossa H. N. England (1935, 14)

felspar and the quartz are frequently granulated, and these two minerals may show sutured junctions. This fact, with the varying sericitization of the felspars, usually more advanced in the plagioclase, gives evidence of the dynamic metamorphism to which the rocks have been subjected. The augen are set in a groundmass of fine sericite in which wisps of biotite and chlorite show very clearly the foliation direction. Strings of fine granules of sphene are often associated with this biotite. Occasionally small nests of biotite flakes, most of which may be transverse to the foliation direction, are apparently the results of retrograde changes on some former component. There are no relics to indicate with certainty the nature of the pre-existing minerals. Iron ore in spongy masses is common and is frequently associated with sphene and sometimes with biotite. Accessory minerals which may be present are epidote, muscovite, calcite, orthite and tourmaline (pl. viii, fig. 3).

The above general description may be applied to the rocks of which analyses are given in columns i-iii in Table B. For comparison there is given in column iv

TABLE B

Analyses of Augen-gneisses

	i	ii	iii	iv
SiO_2	66·89	71·19	69·69	66·52
TiO_2	0·80	0·50	0·90	0·55
Al_2O_3	14·96	15·26	15·51	14·86
Fe_2O_3	2·53	1·66	2·22	1·92
FeO	1·73	1·05	1·29	3·96
MnO	0·01	—	—	0·09
CaO	1·59	0·56	0·44	1·82
Na_2O	2·13	2·64	2·84	3·29
K_2O	5·54	5·87	4·91	5·42
P_2O_5	0·17	—	—	0·12
H_2O+	1·23	0·96	1·12	0·95
H_2O-	0·22			0·20
CO_2	0·89	—	—	tr.
ZrO_2	nil	—	—	(S = 0·02)
	100·26	100·47	100·02	100·39
Norms				
Quartz	30·36	31·02	31·80	19·98
Orthoclase	32·80	34·47	28·91	31·69
Albite	17·82	22·53	24·10	27·77
Anorthite	1·67	2·78	2·22	8·62
Corundum	4·90	3·57	4·69	0·51
Hypersthene	3·90	2·00	2·80	6·56
Magnetite	3·25	2·04	1·62	2·78
Haematite	0·32	0·16	1·12	—
Ilmenite	1·52	0·91	1·67	1·06
Apatite	0·34	—	—	0·34
Calcite	2·00	—	—	—

i Augen-gneiss (S.P. 1) South Para River, near section 3,779, Hundred of Para Wirra Anal. A. R. Alderman

ii Augen-gneiss (BA. 3) South Para River, quarry at ford near east end of Sect. 178, Hundred of Barossa Anal. A. R. Alderman

iii Banded augen-gneiss (BA. 17) South Para River, near west end of Sect. 178, Hundred of Barossa Anal. A. R. Alderman

iv Mica-rich-augen-gneiss, Bru, Norway Anal. O. Roer. V. M. Goldschmidt (1920, 93)

of this table the analysis of an augen-gneiss from the island of Bru, near Stavanger. This rock has been shown by Goldschmidt (1920) to have been produced by injection-metamorphism, and further reference to it will be made at a later stage in this paper.

In general the central mass of augen-gneiss passes outwards into fringing zones of banded injection-gneiss and veined schists. Occasionally, however, near the edge of the true augen-gneiss occur small exposures of a massive rock, of fine to medium granularity, which does not appear to be of purely igneous parentage. For convenience the name "soda-hybrid" is applied to these rocks. Typical examples occur in the South Para River near the southern corner of Section 179, Hundred of Barossa *(e.g.,* BA. 21), and near the southern extremity of Section 183, Hundred of Barossa *(e.g.,* BA. 52). In form these small masses of hybrid rock seem to be in irregular bands or lenses, a few feet in thickness, which are parallel to the foliation direction of the augen-gneiss and the surrounding gneisses and schists. The exact shape of the hybrid masses is, however, difficult to determine.

Under the microscope a typical soda-hybrid (BA. 21) is seen to consist of porphyroblasts of quartz and microperthite in a finer granoblastic groundmass of oligoclase, quartz, orthoclase and biotite with a good deal of sericite. Spongy iron ore, apatite and muscovite with small quantities of epidote and sphene are also present (pl. ix, fig. 4). The sutured margins of contiguous quartz grains and the general marginal granulation of the larger minerals indicate the strong dynamic-metamorphism to which the rocks have been subjected. A chemical analysis of this rock is given in Table C. Other examples of this type *(e.g.,* BA. 52) have less prominent porphyroblasts but are mineralogically similar to that described above.

Table C

Soda-hybrid (BA. 21) (2)

			Norm	
SiO_2	59·26			
TiO_2	0·49		Quartz	2·10
Al_2O_3	22·94		Orthoclase	20·02
Fe_2O_3	2·41		Albite	60·26
FeO	1·49		Anorthite	3·06
MgO	1·00		Corundum	6·43
CaO	0·63		Hypersthene	2·50
Na_2O	7·13		Magnetite	3·48
K_2O	3·42		Ilmenite	0·91
H_2O	1·33			
	100·10			

It will be seen from the analysis that silica, alumina and the alkalis comprise over 90% of the rock, also that soda is in considerable excess over potash. In the norm these points are reflected in the absolute dominance of alkali felspar over the other normative minerals. The bulk analysis of the rock cannot be very different from that of a soda-rich perthite. The genetic relationship between this soda-hybrid and the associated augen-gneisses (see Table B) appears, at first sight, to be obscure.

(2) Anal. A. R. Alderman

In a number of places in the section along the South Para River the augen-gneisses are seen to merge outwards into fine banded-gneiss and thence into schists (of sedimentary origin) which contain a few bands of felspathic material. The banded-gneisses appear from their field relations to be directly related both to the augen-gneisses and to the schists, and this relationship appears to be confirmed by the texture and mineral composition exhibited by specimens of the rocks themselves. Mineralogically the banded-gneisses resemble the augen-gneisses, as fine bands of pinkish quartz-felspar, occasionally swelling into small augen, are separated by equally fine bands of grey sericitic material. Texturally they appear to be related to the slightly pegmatized grey sericite schists, the chief differences being in the greater number and size of the quartz-felspar layers in the banded-gneisses.

The chemical analysis of a rock which can be taken as typical of the banded-gneisses (BA. 49) is given in Table D. This is *in situ* in the bed of the South Para River, near Section 3,279, Hundred of Para Wirra, and fringes a great "enclave" of schist in the augen-gneiss. With a decrease in the number and size of the quartz-felspar bands the banded-gneiss merges into the slightly pegmatized schist. With an increase in the prominence of the quartz-felspar the same rock passes into typical augen-gneiss.

The average thickness of the light quartz-felspar layers and of the dark sericitic layers in a typical banded-gneiss is about the same, each being slightly more than 1 mm. thick. Under the microscope the felspar is found to be essentially microperthite. Flakes of pale brown to greenish-brown biotite are arranged in the direction of foliation. Spongy iron ore, much of it showing the change to leucoxene, is plentiful. Also present are small grains of epidote, an occasional grain of orthite and a sprinkling of calcite (pl. viii, fig. 2).

TABLE D

Banded-gneiss (BA. 49) [3]

			Norm.	
SiO_2	68·31			
TiO_2	0·82		Quartz	31·68
Al_2O_3	15·12		Orthoclase	31·14
Fe_2O_3	2·52		Albite	20·44
FeO	1·46		Anorthite	1·39
MgO	1·22		Corundum	4·90
CaO	0·91		Hypersthene	3·10
Na_2O	2·41		Magnetite	2·55
K_2O	5·33		Haematite	0·80
H_2O	1·11		Ilmenite	1·52
CO_2	0·55		Calcite	1·10
	99·76			

If the composition of the banded-gneiss (BA. 49) is compared with that of any of the augen-gneisses given in Table B (columns i, ii and iii), it will be seen

(3) Anal. A. R. Alderman

that the closest relationship exists between them. It has also been noted that in its field relationships and texture the banded-gneiss is closely related to slightly pegmatized schist of sedimentary origin, the main apparent difference between these two types lying in the greater size and number of the quartz-felspar bands possessed by the banded-gneiss. It would appear, therefore, that these two rock types, the banded-gneiss and the schist, were originally similar and that they now differ only in the degree in which they have been pegmatized.

The banded-gneisses thus seem to provide a most interesting link between the augen-gneisses and the sedimentary schists, and in order to investigate this suggestion the composition of the latter rock types will now be discussed.

III The Schists

The broad field relations between the main body of augen-gneiss and the surrounding schists in the South Para section have been excellently shown by Hossfeld (1935, 23). The more intimate relations between these two rock types have already been mentioned in this paper.

The schists which are to be seen in the section seem to be of very uniform type and composition. In some localities, *e.g.*, the southern corner of Section 180, Hundred of Barossa, definite bands of extreme granulitization may be recognised. The trend of these granulitic bands is north-south, this being in conformity with the direction of foliation of both the schists and the augen-gneisses. On the whole, however, the schists which are adjacent to the augen-gneisses exhibit a great uniformity of texture and appearance. They are, for the most part, fine-grained grey rocks in which very fine bands of light-coloured quartz and felspar are often to be seen parallel to the foliation (pl. viii, fig. 1). These rocks are also intersected by comparatively coarse veins of pegmatite or of quartz, the veins measuring up to an inch or so in thickness. These coarser veins may cut across the direction of foliation and seem to belong to a later stage in the rock's metamorphic history.

Analyses are given in Table E of two rocks which may be taken as typical of the grey schists. Of these, BA. 23 occurs in the gorge of the South Para River a few yards from the augen-gneiss near the north-east corner of Section 289, Hundred of Para Wirra. S.P. 3, which was collected and incompletely analysed a few years ago, occurs in a similar situation but near Section 3,279, Hundred of Para Wirra. Under the microscope these rocks are seen to consist largely of fine sericitic mica containing small flakes of biotite. The direction of foliation is strongly marked in these micaceous minerals, and is also well shown by the plentiful micro-augen of quartz and of microperthite. In this same direction the rock is sometimes strongly granulitized in narrow bands. Of the same general size and shape as the micro-augen of quartz and microperthite there may be seen lenticular aggregates of fine chloritized biotite with fine flakes of muscovite, powdery iron ore and some exceedingly fine needles which may be rutile. In these aggregates the mica flakes do not follow the direction of foliation of the rock, and the aggregates themselves seem to represent some former mineral on which retrograde changes have acted. The usual accessory minerals in these rocks are iron ore, tourmaline, apatite, epidote and occasional grains of rutile.

The analyses stated in Table E indicate several points of interest. Firstly, that the grey schists have a very constant composition. The analyses in columns i and ii are of rocks occurring approximately a mile apart. Secondly, a comparison of columns i and ii with columns iii and iv indicates that the South Para schists have a composition which is quite usual for rocks of that type. Thirdly, a comparison of the norm in column i with the norms of any of the augen-gneisses shown in Table B, shows that the only important points of difference in the normative compositions of these two very different rock types lie in the greater amount of corundum and smaller amount of albite in the schist. It will be seen that if more soda and silica were to be added to the schist, thus converting its corundum into albite, a rock very similar in composition to the augen-gneiss would be produced.

TABLE E

Analyses of Schists

	i	ii	iii	iv
SiO_2	61·53	60·02	58·32	60·70
TiO_2	0·75		0·98	1·32
Al_2O_3	20·70	21·84	20·00	19·79
Fe_2O_3	2·96	4·67 (4)	2·01	3·63
FeO	2·35		4·98	3·63
MgO	1·69	2·11	1·85	0·98
CaO	0·26	0·43	0·66	0·68
Na_2O	0·71	1·09	1·26	0·42
K_2O	6·24	6·25	4·49	6·44
H_2O	2·87	n.d.	4·10	1·88
Etc.			1·32	0·68
	100·06		99·97	100·15
Norms				
Quartz	30·42		28·26	31·02
Orthoclase	36·70		26·69	37·81
Albite	5·76		10·48	3·14
Anorthite	1·39		0·28	1·67
Corundum	12·34		12·95	11·63
Hypersthene	4·86		10·54	4·12
Magnetite	4·41		3·02	5·34
Ilmenite	1·37		1·98	2·93
Etc.			1·36	0·84

i Sericite-schist (BA. 23), South Para River, near Sect. 289, Hundred of Para Wirra Anal. A. R. Alderman

ii Sericite-schist (S.P. 3), South Para River, near Sect. 3,279, Hundred of Para Wirra Anal. A. R. Alderman

iii Quartz-muscovite-chlorite-phyllite Stavanger district, Norway Anal. O. Roer V. M. Goldschmidt (1920, 58)

iv Mica-schist, Portnockie, Banffshire Anal. E. G. Radley E. M. Guppy (1931, 120)

(4) Total iron as Fe_2O_3

IV Pegmatization of the Schists

The above description of the Humbug Scrub augen-gneisses and of their field relations is believed to indicate the following points:

(i) The chemical and mineralogical composition of the augen-gneisses suggests that these rocks are not of entirely igneous origin. Further, they differ materially from the known igneous rocks of the region (Table A) and resemble rocks whose origin is recognised as being due to injection-metamorphism (Table B).

(ii) The augen-gneisses merge outwards into banded-gneisses, which in turn pass, with decreasing pegmatization, into grey schists. The banded-gneiss has been shown to be chemically identical with the true augen-gneiss (Table D).

(iii) If banded-gneiss is formed by pegmatitic injection of the grey schists it would then appear that the augen-gneisses owe their origin to the same process.

If an examination of these rocks was based on field evidences alone the injection-metamorphism would appear to be a comparatively simple process consisting of the lit-par-lit injection into the schists of quartz-felspar pegmatite. The textural properties of the augen-gneisses and their associates would have developed in a subsequent period of dynamic metamorphism.

A comparison of the chemical composition of the schists with that of the banded- and augen-gneisses shows, however, that the injecting material cannot have been quartz-felspar pegmatite. On the other hand, it will be seen that by adding to the schist a mixture consisting largely of sodium silicate the product may have a composition identical with that of average augen-gneiss, if some water is lost in the process. Table F shows the effect of adding to an average South Para schist (column i, average of two analyses in Table E) a mixture of 35·7 parts of silica, 2·7 parts of soda, 1·3 parts of potash and 0·8 parts of lime. Water in the proportion of 1·2 parts is subtracted (column ii). Column iii gives the resulting mixture and column iv the composition of average augen-gneiss taken from the three analyses in Table B.

Table F

	i Average Schist (by Analysis)	ii Additive Mixture (Calculated)	iii Resulting Mixture (Calculated)	iv Average Augen-gneiss (by Analysis)
SiO_2	60·27%	35·7 parts	68·9%	69·26%
TiO_2	0·75		0·5	0·73
Al_2O_3	20·89		15·0	15·24
FeO (total iron)	4·60		3·3	3·28
MgO	1·90		1·4	1·15
CaO	0·35	0·8	0·8	0·86
Na_2O	0·90	2·7	2·6	2·54
K_2O	6·25	1·3	5·4	5·44
H_2O	2·87	(−1·2)	1·2	1·18

It will be seen that an adequate explanation of the chemistry of the injection-metamorphism can be offered if it is assumed that the added material consisted of alkali-lime-silicate. It is interesting to compare this explanation with that of Goldschmidt (1920), who showed that the augen-gneisses of the Stavanger region were probably produced from phyllites by the addition of a mixture consisting of SiO_2 34 parts, CaO 2 parts, Na_2O 3·3 parts, K_2O 2·3 parts, and the loss of 2·6 parts of H_2O.[5] Goldschmidt's conclusions were based on a very complete series of analyses. The same writer has also shown in a later paper (1922) that if the concentration of such alkali-silicate solutions—"a kind of water-glass"—is greater than a certain minimum they constitute highly potent metasomatic agents.

The close correspondence between the apparent metasomatic reactions in the South Para and the Stavanger regions is very notable. There is also a striking similarity between the calculated compositions of the incoming alkali silicates in both localities. Another locality where a similar action may have taken place is Cromar, Deeside, Aberdeenshire, where, it has been suggested by Read (1927), oligoclase-porphyroblast-schists may owe their origin to a similar type of injection-metamorphism.

The injection-metamorphism in the South Para region may thus be pictured as a lit-par-lit injection into the sericite schists of alkali-silicate solutions. This would be accompanied by a certain amount of permeation from the main narrow channels of injection and a metasomatic change of the sericitic mica, alkali-felspar being the main product of this metasomatism. The chemistry of this change may be simply represented by the following equation:

$$\underset{\text{sericite}}{(OH)_2Al_2[Al\,Si_3O_{10}]K} + \underbrace{Na_2SiO_3 + 5SiO_2}_{\text{"water-glass" solution}}$$

$$= \underset{\substack{\text{alkali-felspar}\\ \text{(microperthite)}}}{\begin{matrix} K[Al\,Si_3O_8] \\ 2Na[Al\,Si_3O_8] \end{matrix}} + \underset{\text{water}}{H_2O}$$

The type of metasomatism displayed by such a reaction is that in which excess alumina—in this case in the sericite—is bound by the incoming alkalis. Goldschmidt (1922, 120) has shown that in such metasomatic processes a minimum concentration of the alkali silicate is necessary, at a given temperature and pressure, to cause the separation of felspar at the expense of mica. If this minimum concentration of alkali silicate does not exist, the circulating solution can only leach the mica, but not deposit any felspar.

It is thus evident that where the alkali solution is of low concentration it will gradually become saturated with alumina, and with falling temperature will eventually solidify as a rock or pegmatite largely composed of felspar. In Table G the calculated composition of such a felspar rock is given. This is obtained from the calculated composition of the "water-glass" solution by adding enough alumina to saturate the alkalis and lime.

---

[5] Analyses of the Stavanger augen-gneiss and phyllite are quoted in Tables B and E

TABLE G

	Composition of Silicate Solution Parts	Per cent.	Mineral Composition of Felspar Rock	
SiO_2	35·7	88·1		
CaO	0·8	2·0	Anorthite	11·7%
Na_2O	2·7	6·7	Albite	66·2
K_2O	1·3	3·2	Orthoclase	22·1

	Calculated Chemical Composition of Felspar Rock	Chemical Composition of Soda-hybrid (BA. 21)
SiO_2	65·0	59·26
TiO_2		0·49
Al_2O_3	21·2	22·94
FeO (total iron)		3·66
MgO		1·00
CaO	2·3	0·63
Na_2O	7·8	7·13
K_2O	3·7	3·42
H_2O		1·33

It will be seen that the calculated chemical composition of the felspar rock —formed by the solution of alumina in "water-glass"—has a surprisingly close correspondence with that of the soda-hybrid (BA. 21) previously described (Table C). The addition of about 7% of iron, magnesium and water to the felspar rock would make the two compositions almost identical. This comparison thus seems to provide an adequate explanation of the genesis of the soda-hybrids, as well as a confirmation of the activity of the water-glass solutions.

V METAMORPHIC HISTORY AND CORRELATION

In a review of the processes of injection-metamorphism Read (1931, 146-150) concludes that the conditions necessary for such injection are "activity of stress and prevalence of high temperatures in the country-rock of the complex." In mountain-building movements accompanied by intrusion of magma these conditions are provided immediately after a tectonic maximum. In the Loch Choire complex in Sutherland Read has shown that the metamorphic grade of the injected rocks is raised, and sillimanite occurs only within the injection complex.

In the South Para section sillimanite and other high grade minerals have not been detected. This may be due to one or both of two factors: (1) The South Para gneisses having apparently been produced from a process of injection combined with permeation, the formation of sillimanite and allied minerals may have been prevented by the presence of alkali-silicate solutions; or if such minerals had already developed in the schists, these solutions may have converted them back to mica. Read (1927, 333) has described the change of sillimanite, andalusite, garnet and staurolite to micaceous "shimmer-aggregates" in the injection complex of Cromar, and suggests that these changes are due to the passage through the rock of alkali-silicate solutions; (2) minerals of high metamorphic grade may have been changed by retrogression during the subsequent stage of dynamic metamorphism. In such a change mica would again be the main product of the retrograde processes.

Occasionally some rounded inclusions and other enclaves of schist occur in the augen-gneiss. These seem to be blocks of country rock which have resisted or been protected from injection. They may resemble the rounded inclusions of eclogite which occur in the injection-gneisses of Inverness-shire (Alderman, 1936, 527) and thus be residual kernels of the country-rock which have escaped injection. It would appear that the contact between augen-gneiss and schist mentioned by Hossfeld (1935, 25) is of this nature, the country-rock forming a promontory or large enclave which has not been injected.

The source of the alkali-silicate solutions is as yet indefinite. At Stavanger the source has been convincingly traced to an igneous intrusion of trondhjemitic composition. At Loch Choire and at Cromar the parent igneous rock is not obvious, but it would appear that one of trondhjemitic composition is again the most likely. In the Barossa district intrusive igneous rock may be hidden in the Humbug Scrub region to the south of the South Para River, but information and evidences on this point are very vague. Hossfeld (1935, 52) mentions the possibility of the pegmatization of the Barossian schists being contemporaneous with the intrusion of the igneous rocks at Houghton and Mount Kitchener. The diorite described by England (1935) from Section 257, Hundred of Barossa, would also be included in this possibility. The other large igneous masses of this region, the Tanunda Creek and Palmer adamellites, seem to be of later date than the period of injection-metamorphism.

Following or perhaps partly contemporaneous with the injection-period the augen-gneisses, and the other rocks of the South Para section, were subjected to strong dynamic metamorphism. This may have immediately followed on the injection stage and produced the final effects of the single tectonic period. With falling temperatures the kind of metamorphism would change from an injection type to conditions in which shearing stress was dominant. The presence of granulitized bands with a north-south trend in the schists, and particularly in the region to the south and west of the South Para section, seems to indicate strong thrusting movements from the west (pl. ix, fig. 6). These were evidently of later date than the injection period.

That the rocks within the injection complex must have been subjected to strong internal stresses produced by the injection is evident from a consideration of the mineralogical changes. It will be seen from Table F that about 100 parts by weight of schist react with about 40 parts of "water-glass" to produce augen-gneiss. However, it will be seen from the following equation that, theoretically, sericite and water-glass can react in approximately equal amounts to form felspars. Molecular weights are given beneath the empirical formulae.

$$\underbrace{(OH)_2Al_3Si_3O_{10}K}_{\substack{\text{sericite}\\398}} + \underbrace{Na_2Si\,O_3 + 5Si\,O_2}_{\substack{\text{water-glass}\\422}}$$

$$= \underbrace{K\,Al\,Si_3O_8}_{278} + \underbrace{2Na\,Al\,Si_3O_8}_{524} + \underbrace{H_2O}_{\text{water}}$$

(felspars: $K\,Al\,Si_3O_8 + 2Na\,Al\,Si_3O_8$)

From these considerations it would appear that about $\frac{2}{5}$ of the schist was effected by the metasomatic change. The increase, produced by this metasomatism in the volume of the rock is shown by comparing the volumes of the constituent minerals before and after the reaction. The sizes of the molecules of muscovite, orthoclase and albite are given by the volumes of each mineral in cubic Angstrom units per oxygen atom. These figures are for muscovite, 19·2, orthoclase 23, albite 21·6. The volume change of the solid constituents is, therefore:

$$\underset{230 \cdot 4}{\underset{19 \cdot 2 \times 12}{\text{muscovite}}} \longrightarrow \underbrace{\underset{23 \times 8}{\text{orthoclase}} + \underset{2 \times 21 \cdot 6 \times 8}{\text{albite}}}_{529 \cdot 6}$$

This shows that at normal temperatures and pressures about two-fifths of the rock would increase to about two and a quarter times its original volume as a result of the metasomatism. The whole rock would, therefore, nearly double its volume.

Although these calculations cannot give an exact idea of the volume changes produced under natural conditions and under high temperatures and pressures, they at least indicate that the metasomatism will cause a great increase in the volume of the rocks concerned. This volume change would, undoubtedly, set up great internal stresses in the augen-gneisses and may thus account for much of the retrogressive change and granulation exhibited by these rocks.

VI Summary

The Humbug Scrub augen-gneisses, which are an important feature of the Barossian (Pre-Cambrian) series in South Australia, are well shown in the gorge of the South Para River. They appear to have been developed during a period of injection-metamorphism in which alkali-silicate solutions reacted with the sericite-schists of the complex. This process normally produced augen-gneisses and banded-gneisses, but when the concentration of the metasomatic solutions fell below a certain level hybrid rocks rich in soda were formed. One of the results of the injection and metasomatism would be a large increase in volume, to which may be ascribed many of the effects apparently due to subsequent dynamic-matomorphism.

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Fig. 1

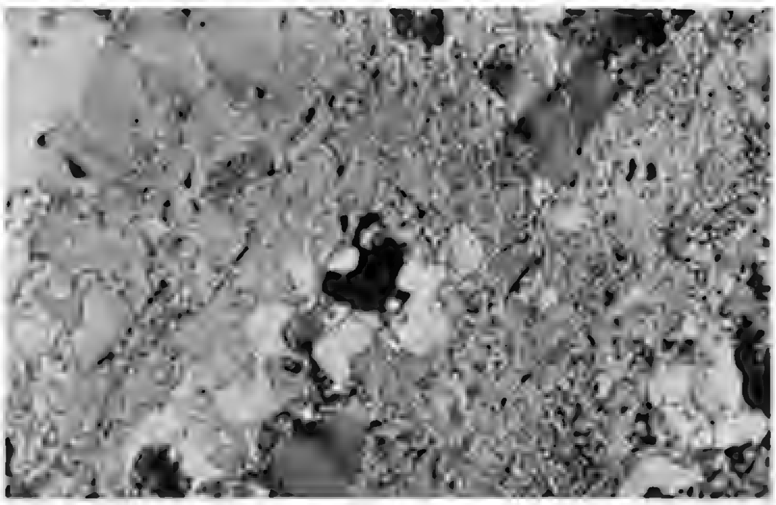

Fig. 2

Fig. 3

Photos by H. E. E. Brock

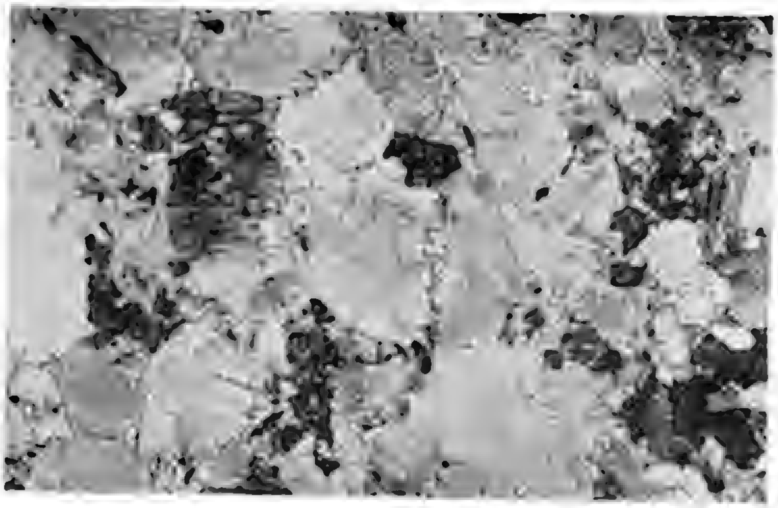

Fig. 4

Fig. 5

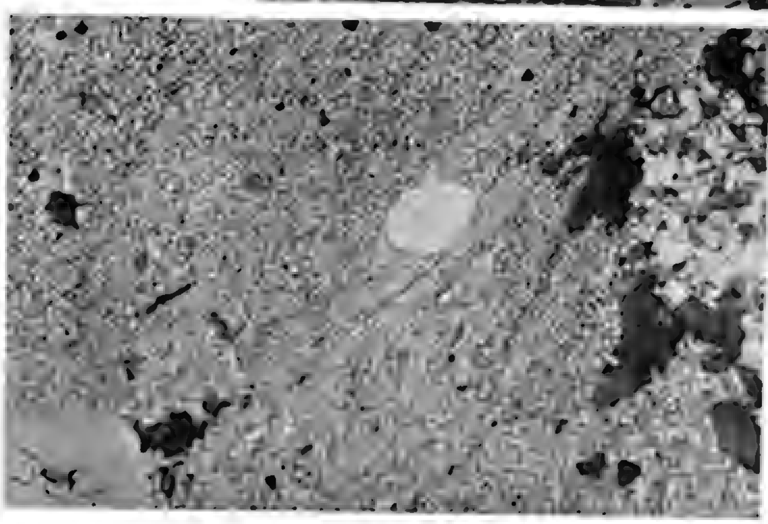

Fig. 6

Photos by H. E. E. Brock

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PLATE VIII

Fig. 1 Schist BA. 23 x 25 Small grains and micro-augen of quartz and felspar in the sericite base indicate slight pegmatization of the schist

Fig. 2 Banded gneiss BA. 49 x 25 Definite bands of quartz felspar in sericite

Fig. 3 Augen-gneiss BA. 27 x 25 Microcline-microperthite augen in sericite base

PLATE IX

Fig. 4 Soda-hybrid BA. 21 x 25 The rock consists largely of microperthite and quartz in a finer groundmass of oligoclase, quartz, sericite, etc.

Fig. 5 Microcline microperthite in augen-gneiss. BA. 3 x 33

Fig. 6 Granulite BA. 29 x 33 Lenticles of quartz and granulitized quartz and felspar in a fine granulitic base

The microphotographs were made by Mr. H. E. E. Brock in the Department of Geology, University of Adelaide

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ON SOME REPTILES AND AMPHIBIANS FROM THE CENTRAL REGION OF AUSTRALIA

By ARTHUR LOVEREDGE,
Museum of Comparative Zoolcgy, Cambridge, Mass, U.S.A.
(Communicated by H. H. Finlayson)

Summary

In view of the relative poverty of our knowledge concerning the ecology and distribution of the herpetofauna of the central area of the continent, it seems advisable to publish the following notes based on part of the collection gathered by Mr. H. H. Finlayson during some of the journeys which he made through that region in 1933-1935.

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[Read 12 May 1938]

In view of the relative poverty of our knowledge concerning the ecology and distribution of the herpetofauna of the central area of the continent, it seems advisable to publish the following notes based on part of the collection gathered by Mr. H. H. Finlayson during some of the journeys which he made through that region in 1933-1935.

Most of the material comes from Officer Creek, which lies midway between the Everard and Musgrave Ranges in the far north-west of South Australia; others from Palm Creek in the Macdonnel Range. The homogeneity of the fauna throughout this area is emphasised by noting that of the twenty-two species taken, no fewer than thirteen were also collected at Hermannsburg on the Finke River, Northern Territory, in 1931, by Mr. W. E. Schevill on behalf of the Museum of Comparative Zoölogy.

In the following notes the letters H.H.F. denote that the specimen is still in the Finlayson collection, while M.C.Z. precedes the catalogue number of those presented to this Museum. Scale counts, or other pertinent matter likely to be of use to future investigators, are given as a check on my determinations. Annotations as to the aboriginal name, colour in life, etc., made by the collector are included, together with some observations on breeding and diet. Attention is particularly directed to the voraciousness displayed by the gecko, *Nephrurus laevis*, as well as the discovery of the adult skink, *Egernia inornata*.

Typhlops bituberculatus (Peters)

Onychocephalus bituberculatus Peters, 1864, Monatsb. Akad. Wiss., Berlin, p. 233; near Adelaide, South Australia.

1 (H.H.F. 21), Officer Creek, S.A., Jan., 1934.

Midbody scale-rows, 20; nasal cleft joining the second labial; head trilobed. Diameter, 5·5 mm., included in total length 49 times. Total length, 271 (268 + 4) mm.

Rhynchoelaps bertholdi (Jan)

Elaps bertholdi Jan, 1859, Rev. et Mag. Zool., p. 123: Australia.

1 (H.H.F. 19), Indi, N.T., 14 Jan., 1935.

Midbody scale-rows 15; ventrals 117; anals 2; subcaudals 21, paired, except for the anterior four; labials 6, the third and fourth entering the orbit. Total length 200 (178 + 22) mm.

The top of the head presents a very different appearance from that of the example figured by Kinghorn (1929, p. 155), it is wholly black except for a light area in the centre of each of the scales anterior to the frontal and eye. There are 24 + 5 annular rings on body and tail, "the interspaces are orange in life." (H. H. F.)

Nephrurus laevis De Vis

Nephrurus laevis De Vis, 1886, Proc. Linn. Soc. N.S.W. (2), **1**, p. 168; Queensland.

♂ (M.C.Z. 43113) Owellinna, Musgrave Range, S.A.

♀ (M.C.Z. 43114) Officer Creek, S.A., Jan., 1934.

These agree closely with a Hermannsburg specimen (M.C.Z. 35106). The larger, a ♀ with a complete tail terminating in a semi-sphere, measures 126 (86 + 40) mm., and holds two developing ova measuring 11 x 6 mm.

In her stomach is a young gecko *(Rhynchoedura ornata)*, a large scorpion, and many parasitic nematodes *(Psysaloptera* sp.).[1] The smaller ♂ has an apparently regenerating tail of a more granular and less spinose appearance.

Heteronota binoei Gray

Heteronota binoei Gray, 1845, Cat. Liz. Brit. Mus., p. 174: Houtman's Abrolhos, Western Australia.

♀ (M.C.Z. 43115) Officer Creek, S.A., Jan., 1934.

Dorsal tubercles in 13 rows. Total length 88 (40 + 48) mm.

Diplodactylus elderi Stirling and Zietz

Diplodactylus elderi Stirling and Zietz, 1893, Trans. Roy. Soc. S. Austr., **16**, p. 161, pl. iv, fig. 1: Barrow Range, Northern Territory.

2 (M.C.Z. 43116-7), Officer Creek, S.A., Jan., 1934.

These handsome little geckos, with a network of black uniting the pure white tubercles on the dorsum, exhibit on the underside of the original tail numerous flat white tubercles like those on the back, but each forming the centre of a circle of black granules. Larger gecko measures 68 (42 + 26) mm.

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(1) I am indebted to Dr. D. G. Davey for this identification.

LIALIS BURTONIS Gray

Lialis burtonis Gray, 1834, Proc. Zool. Soc. London, p. 134: New South Wales.

1 (H.H.F. 20), Officer Creek, S.A., Jan., 1934.

Preanal pores 4; preanal shields 3. Three darker stripes on the grey dorsum, two lateral and two ventral. Total length 327 (167 + 160) mm.

AMPHIBOLURUS MACULATUS GULARIS Sternfeld

Amphibolurus maculatus gularis Sternfeld, 1925, Abh. Senckenberg Naturf. Ges., **38**, p. 231: Hermannsburg Mission, Upper Finke River, Northern Territory.

♂, ♀ (M.C.Z. 43118-9), Officer Creek, S.A., Jan., 1934.

Native name, *Chimpis*, but applied to many other small lizards.

Femoral and preanal pores of ♂ total 62 in all. Neither specimen exceeds 60 mm. from snout to anus, yet the ♀ holds three small spherical ova about 6 mm. in diameter. Her stomach was filled with finely masticated ants.

AMPHIBOLURUS SCUTULATUS Stirling and Zietz

Amphibolurus scutulatus Stirling and Zietz, 1893, Trans. Roy. Soc. S. Austr., **16**, p. 165, pl. vii, figs. 1-2: between Queen Victoria Springs and Fraser Range, Western Australia.

♀ (H.H.F. 16), Officer Creek, S.A., Jan., 1934.

Native name, *Tukul*.

This specimen exceeds in dimensions those I have previously (1934, p. 319) examined, with which, however, it has been carefully compared. The arrow-like marking on the head is light buff in this alcohol-preserved individual. Total length 345 (105 + 240) mm. Gravid with 5 eggs, each measuring approximately 20 x 10 mm.

AMPHIBOLURUS RETICULATUS INERMIS (De Vis)

Grammatophora inermis De Vis, 1888 (1887), Proc. Linn. Soc. N.S.W., (2), **2**, p. 812: Central Queensland.

♂, 3 ♀ (M.C.Z. 43120-3), Officer Creek, S.A., Jan., 1934.

Native name, *Linga*.

Femoral and preanal pores of ♂, 23. Total length of ♂, 246 (102 + 144) mm; largest perfect ♀, 172 (82 + 90) mm; youngest (H.H.F. 13) measures 87 (37 + 50) mm.

AMPHIBOLURUS DIEMENSIS (Gray)

Grammatophora muricata var. *diemensis* Gray, 1841, in Grey, Journ. Exped. Western Australia, **2**, p. 439 : Tasmania.

♂ (H.H.F. 15), Officer Creek, S.A., Jan., 1934.

Apparently the first record of the occurrence of this species in Central Australia.

Keels on the snout very strong and tending to form ridges extending back to the interorbital region; the adpressed hind limb reaches to between tympanum and eye; femoral and preanal pores 15 in all. Total length 142 (51 + 91) mm.

PHYSIGNATHUS LONGIROSTRIS (Boulenger)

Lophognathus longirostris Boulenger, 1883, Ann. Mag. Nat. Hist., (5), **12**, p. 225: Champion Bay and Nicol Bay, Western Australia.

♀ (H.H.F. 17), South's Range, N.T., 20 Jan., 1935.

Keels of the upper dorsal series obliquely directed towards the vertebral line; nostril a little nearer the orbit than to the tip of the snout; tail roundish. This identification is made with the same reservation as regards the validity of *quattuorfasciatus* Sternfeld as I (1934, p. 329) have already made. No lower light streak on the flank is discernible. Mr. Finlayson, however, states than "an area of blue is present on the sides during life, though it is now absent." He adds that the species is very common over most of Central Australia, is readily tamable, and is a good fly-catcher.

VARANUS GOULDII (Gray)

Hydrosaurus gouldii Gray, 1838, Ann. Nat. Hist., **1**, p. 394: Australia.

Young (M.C.Z. 43124), Officer Creek, S.A., Jan., 1934.

This individual agrees with our long series of *gouldii* as defined (1934, p. 332), except that it is immaculate beneath, apart from some obsolescent dusky streaks on the throat. In this respect alone it would appear to conform to *giganteus* (Gray). It is the smallest example of this monitor which I have seen, measuring only 272 (112 + 160) mm.

VARANUS GILLENI Lucas and Frost

Varanus gilleni Lucas and Frost, 1895, Proc. Roy. Soc. Victoria, **7**, p. 266: between Glen Edith and Deering Creek, also Charlotte Waters, Northern Territory.

♂ (H.H.F. 18), South's Range, N.T., 20 Jan., 1935.

Total length 282 (120 + 162) mm.

EGERNIA INORNATA Rosèn

Egernia inornata Rosèn, 1905, Ann. Mag. Nat. Hist. (7), 16, p. 139, fig. 3: Western Australia.

Egernia striata Sternfeld, 1919, Mitt. Senckenberg. Naturf. Ges., 1, p. 79: Hermannsburg Mission, Upper Finke River, Northern Territory.

8 (M.C.Z. 43125-6), Officer Creek, S.A., Jan., 1934.

♀ and embryos (M.C.Z. 43749-50), Pundi, S.A., 8 Jan., 1934.

Skin (H.H.F.), Toonunnya Water, Rawlinson Range, W.A., 27 Jan., 1935.

Native Names: *Moalinga* for the spotted or *striata* type; *tuleeri* for the uniform or *inornata* type; *tcharcoora* for the handsome adults.

For reasons stated below, the scale counts, etc., of the two *tcharcoora* are discussed independently of the series from Officer Creek, which are:

Midbody scale-rows 36-44; length from snout to anus, after elimination of those with regenerated tails, is included in length of tail from 1·01 in the largest to 1·2 in the smallest. These two skinks measured 95 (43 + 52) and 208 (103 + 105) mm., respectively.

The *tcharcoora* (M.C.Z. 43749) is the specimen which formed the subject of the photograph facing page 62 of Mr. Finlayson's book, "The Red Centre." In life its dorsum was a rich shining cupreus red, the flanks were banded alternately with red and yellow (possibly also with bluish-green, according to Mr. Finlayson's recollection); the undersurface was a very clear, bright lemon-yellow. These colours have faded in the alcoholic-preserved reptile, but are present to some extent in the salt-prepared skin from Toonunnya water; this is particularly the case with the belly, which has retained its bright lemon-yellow hue.

The midbody scale-rows are 46 or 48 in these two big skinks, whereas the range shown by the twenty-four examples from Hermannsburg and Teatree Well (Loveridge, 1934, p. 337) was only 38-46, those from Teatree averaging higher than the more westerly Hermannsburg series. As none of these skinks exceeded 228 mm. in length, I dissected several but without finding signs of enlarged gonads in any, so that I was lead to the conclusion that both they and the Officer Creek series listed above are immature individuals. On dissecting the 376 mm. Pundi *tcharcoora*, however, she was found to be a gravid female bearing four embryos when killed on 8 January, 1934. These embryos varied a good deal in tail length, one, a ♂, measured 78 (43 + 35) mm. and had 46 midbody scale-rows. It is interesting to compare its length with that of an active juvenile from Officer Creek as given above. The length from snout to anus of mother and embryo is included in the length of tail 1·005 and ·81 times, respectively.

Mr. Finlayson, not unnaturally, concluded that the *tcharcoora* represented a distinct species, but in the absence of any scale characters which serve to separate them, and for the reasons stated above, I conclude that he has secured the first adults of *inornata*, a species with a midbody scale formula of 36-48; whether *striata* may eventually be recognised as a race remains to be seen.

Tiliqua occipitalis occipitalis (Peters)

Cyclodus occipitalis Peters, 1863, Monatsb. Akad. Wiss., Berlin, p. 231: Adelaide, South Australia.

2 (M.C.Z. 43747-8), Officer Creek, S.A., Jan., 1934.

Coming, as they do, from the far north-west of South Australia, these skinks assist in bridging the gap between the nominate form and the race which is common in central and north-west Australia.

Midbody scale-rows 40; supraoculars 2; supraciliaries 5; frontonasal separated from frontal. Bands on body 4, on tail 3. Larger skink measures 405 (275 + 130) mm.

Tiliqua occipitalis multifasciata Sternfeld

Tiliqua occipitalis multifasciata Sternfeld, 1919, Mitt. Senckenberg Naturf. Ges., 1, p. 79: Hermannsburg Mission, Upper Finke River, Northern Territory.

1 (M.C.Z. 43128), Sandhills south of Koonapandi, Musgrave Range, S.A.

Native name, *Culameer, i.e.,* differing from that in use at Anningie.

Midbody scale-rows 40; auricular lobules 4; frontonasal separated from frontal. Transverse bands on body 12, on tail 10; in life these "were orange, the intermediate areas olive green" (H.H.F.). My colleague, Dr. P. J. Darlington, could only detect the remains of ants, though of several species, among the masticated mass which distended the stomach and enormous intestinal tract.

Tiliqua casuarinae petersi (Sternfeld)

Lygosoma (Lygosoma) mülleri Peters (*non* Schlegel), 1878, Sitzber. Ges. Naturf. Freunde, Berlin, p. 191: South Australia.

Lygosoma (Homolepida) petersi Sternfeld, 1919, Mitt. Senckenberg Naturf. Ges., 1, p. 81: Hermannsburg Mission, Upper Finke River, Northern Territory.

1 (M.C.Z. 43127), Officer Creek, S.A., Jan., 1934.

Midbody scale-rows 26; supraoculars 3; digits 5; toes 5; agreeing in all respects with our topotypical material (*vide* Loveridge, 1934, p. 366). Total length 175 (95 + 80) mm.

While the finding of this skink in South Australia removes my doubts as to *mülleri* and *petersi* being syonymous, the status of *mülleri* is unaffected by its transfer to the genus *Tiliqua*, for the name remains preoccupied in *Lygosoma*.

This species, the length of whose hind limb equals the distance between the centre of the eye and the fore limb, differs in this respect from the definition of Section I (*Sphenomorphus*, inc. *Hinulia*) of *Lygosoma* as given by Boulenger (1887, p. 212). In 1934 I followed Sternfeld in referring it to *Omolepida*. Recently Malcolm Smith (1937, p. 233), in studying the status of many skinks formerly included in the genus *Lygosoma*, found that in dentition, as well as in having the parietals completely separated by the interparietal, *casuarinae* agrees with *Tiliqua*. He also transfers to that genus *branchiale*, *gastrostigma* and *woodjonesi*. While the two *c. casuarinae* and three topotypical *c. petersi* have the parietals completely separated, in the Officer Creek specimen they are just in contact behind the interparietal.

It might be as well to invite attention here to the fact that Dr. Malcolm Smith (1935, p. 279) has also shown that certain oriental species so bridge the alleged gap between *Lygosoma* (*sensu strictu*) and *Sphenomorphus* that it is impossible to retain the latter as a distinct genus, and considers that it should be treated only as a section. If this view is accepted, then the Australian species referred to *Sphenomorphus* and *Leiolopisma* must revert to the older name of *Lygosoma*, which will involve some radical changes in their nomenclature.

Lygosoma (Leiolopisma) trilineatum (Gray)

Tiliqua trilineata Gray, 1839, Ann. Nat. Hist., (2), p. 291: Australia.

1 (H.H.F. 12), Officer Creek, S.A., Jan., 1934.

Midbody scale-rows 24; frontoparietal single; supraciliaries 6; adpressed hind limbs do not nearly meet, pentadactyle; lamellae beneath fourth toe 20. Total length 117 (47 + 70) mm.

Ablepharus greyii (Gray)

Menetia greyii Gray, 1844, Zool. Erebus and Terror, Rept., pl. v, fig. 4: Western Australia.

1 (H.H.F. 14), Officer Creek, S.A., Jan., 1934.

Midbody scale-rows 22; supranasals absent; frontoparietals single; interparietal distinct; digits 4; toes 5. Total length 62 (30 + 32) mm., but the tail is regenerated.

Limnodynastes sp.

3 (M.C.Z. 22386 and H.H.F. 24), Ernabella Creek, N.T., 28 Jan., 1934.

2 juveniles (M.C.Z. 22384-5), Palm Creek, N.T., 30 Dec., 1934.

The largest measures 43 mm., a juvenile only 26 mm. Two of the adults were in embrace, the pale yellow male superimposed on the duller brown female. All exhibit the more extensive webbing of the toes characterising a new species being described by Mr. H. W. Parker (in press) as distinct from *ornatus*. There is, however, remarkable divergence in the extent of webbing as between the frogs from Ernabella and Palm Creeks, not more so, however, than is to be observed in a series from Hermannsburg or than has been figured by Spencer under the name of *ornatus*.

It might be remarked here that the Hermannsburg material (M.C.Z. 18530-46) which, following Spencer, I erroneously referred to *ornatus*, and of which examples were sent to most Australian museums under that name, was subsequently studied by Parker, who has designated them paratypes of his recently-described species.

Hyla caerulea (Shaw)

Rana caerulea Shaw, 1790, in White, Journ. Voy. N.S.W., App., p. 248: New South Wales (presumably, not stated).

Hyla gilleni Spencer, 1896, in Rep. Horn Sci. Exped., **2**, p. 173, pl. xv, figs. 14-17: Alice Springs, Central Australia.

1 juvenile (M.C.Z. 22383), Palm Creek, N.T., 30 Dec., 1934.

This young frog, only 24 mm. in length, undoubtedly represents *gilleni*, which I (1935, p. 39) tentatively referred to the synonymy of *caerulea*. Unfortunately the shrivelled condition of this specimen makes it impossible to reach a decision as to whether my action was justifiable. It does exhibit a light antebrachial patch, and apparently the whole upper lip as far as the tympanum was pale blue in life.

Hyla rubella Gray

Hyla rubella Gray, 1842, Zool. Miscellany, p. 57: Port Essington, Northern Territory.

2 juveniles (M.C.Z. 22381-2), Palm Creek, N.T., 30 Dec., 1934.

1 juvenile (M.C.Z. 22380), South's Range, N.T., 20 Jan., 1935.

The largest of these three young frogs is only 19 mm. in length, but they are obviously specifically identical with our Lake Barrine, Queensland series (M.C.Z. 18051-2). The dorsum of the young is greyish while the limbs and lateral line on the flanks are finely punctate, thus presenting a somewhat different appearance from that of the adults. Spencer (1896, p. 170) has already recorded this species from Palm Creek and other localities in Central Australia.

Of this and the two preceding species Mr. Finlayson writes: "I took these frogs in midsummer during heavy rain; an hour after the storm commenced the rocks were swarming with them. The dark ones were rich green; the others red-brown, I think."

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AUSTRALITES, PART I11
A CONTRIBUTION TO THE PROBLEM OF THE ORIGIN OF TEKTITES

BY CHARLES FENNER, D.SC., UNIVERSITY OF ADELAIDE

Summary

I INTRODUCTION

This is the third of a series of papers dealing with investigations into the characters and origin of the peculiar glassy objects called australites, found widely and almost universally distributed over the greater part of the southern two-thirds of the Australian continent, including Tasmania and adjoining islands.

AUSTRALITES, PART III

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[Read 4 July 1938]

Plates X and XI

Contents

I INTRODUCTION

This is the third of a series of papers dealing with investigations into the characters and origin of the peculiar glassy objects called australites, found widely and almost universally distributed over the greater part of the southern two-thirds of the Australian continent, including Tasmania and adjoining islands.

Part I of the series (103) dealt with the classification of the Shaw collection, a representative series of forms numbering 3,920 pieces. Part II (112) consisted of an enquiry into the numbers, forms and distribution of australites, with some speculations as to origin.

In this paper additional facts concerning the forms and distribution of australites are set down, and evidence is presented concerning the probable sequence of development of the "round" forms of australites, together with speculations concerning probable methods of cosmic origin.

During 1937 the writer was privileged to examine the chief tektite collections of the world, and to discuss the associated problem with authorities on such matters in Europe, North America, and South Africa. Further, by the courtesy of Professors von Koenigswald and H. O. Beyer, a considerable amount of new tektite material from Java and Philippine Islands was placed at his disposal. Professors L. A. Cotton and H. C. Richards generously lent their complete collections of Darwin Glass. With this and other material the writer is at present engaged upon a comparative study of the internal and external structures of tektites.

Warmest thanks are due to Mr. W. Baragwanath, Director of the Geological Survey of Victoria, for his continued assistance. For the photographic work acknowledgment is made to the Director of Lands, Mr. E. J. Field, and to Mr. M. E. Sherrah; and for the microscopic photographs of smoke bombs to Mr. R. A. L. Laughton, of the S.A. School of Mines. The kindly assistance and encouragement of Dr. L. J. Spencer is deeply appreciated.

The australite problem can be adequately considered only when viewed as a part of the greater tektite problem. To assist Australian workers in this direction the attached bibliography has been compiled, and it is, for the most part, limited to those papers that are likely to be accessible to and necessary for Australian workers. These references are set out in chronological order, indicating to some extent the development of scientific opinion upon the question.

II THE PRESENT STATUS OF THE TEKTITE PROBLEM

While there may be some truth in the statement that the geologist, petrologist, and mineralogist have done all that they can towards the solution of the tektite problem, and that the work of the physicist, mathematician, and astronomer are now required, it seems likely that the majority of workers in this field will continue to be geologists and mineralogists.

Nevertheless, as instanced by the work of Kerr Grant (41), Tilley (72), and La Paz (122), the contributions from the physical and mathematical points of view are decisive and important. The next significant move probably lies with these methods of study.

The unfolding of the tektite story has taken place over 150 years, slowly at first, but with accelerated pace during the present century. Bits of green glass found in Moravia were analyzed by Dufrenoy (1) in 1787. German and French travellers, in the early 1800's, referred to various glass balls occurring in nature, but these were possibly of volcanic origin.

Moldavites thus appeared in the picture in 1787, 151 years ago. Australites, not under that name, first came into literature with Darwin's reference and figure in 1844 (2), 57 years later. Billitonites were first described by Van Dijk (8) in 1878, another 34 years onward, quoted by Beyer (109). Thus, in the first century of this account, there had been no more than three simple descriptions, with no suggestion of correlation, and no important efforts to discuss the question of origin.

Meantime, in Australian geological and mineralogical literature, there had been numerous records of specimens and localities, usually with an acknowledgment of the mystery of their origin and distribution. At the same time a considerable literature grew up around the moldavites, mostly in the German and Czech languages. Makowsky (quoted by Beyer, 109), compared billitonites and moldavites in 1881, and in 1893 Wichmann discussed and compared moldavites, billitonites, and australites.

The really significant initial papers on the various tektite groups appear to be as follows:

Billitonites - - -	Verbeek	1887	(15)
Moldavites - - -	Bares	1889	(16)
Australites - - -	Walcott	1898	(30)
Tektites - - - -	Suess	1900	(31)
Darwin Glass - - -	Hills	1915	(59)
Indo-Chinites - - -	Lacroix	1932	(88)
Tektites - - - -	Spencer	1933	(90)
Ivory Coast Tektites -	Lacroix	1934	(106)
Java Tektites - - -	von Koenigswald	1935	(108)
Philippine Island Tektites -	Beyer	1935	(109)

By the year 1900, despite the bias given towards volcanic theories by Darwin and others, there had grown up a conviction that an extra-terrestrial origin was indicated. The number and ingenuity of the suggestions put forward then and since are well known. Throughout the story the remarkable shapes and distribution of the australites have exerted a special influence upon the investigations. It seems likely that Streich (18) was the first to advance a meteoritic theory of origin; that was in 1893, in a private letter to Professor A. W. Stelzner, of Freiberg (ref. 18, p. 112).

In 1898, Suess (27) clinched the idea of cosmic origin, and grouped all the known series together as "tektites". This theory has been generally accepted on the Continent, in south-eastern Asia, and in Australia. Although no accepted tektite groups have been reported from the Americas, there are at least six localities in those continents from which claims have been put forward for the existence of tektites.[1]

Since 1900 the outstanding suggestions, from the Australian point of view, have been Dunn's bubble hypothesis, which has proved to be quite unacceptable, the "burning light-metal meteorite" hypothesis, and L. J. Spencer's theory of meteoritic impact. While the latter cannot be accepted for the australites, nor for any of the major groups of tektites, it has given a powerful stimulus to discussion upon these matters, and is favoured by some workers as the explanation of the less widely distributed silica glasses.

In a recent paper (122) La Paz discusses the Great Circle theory of distribution of the tektites, from the point of view of the probability of their occurrence along such great circles under the varying conditions attached to volcanic, fulguritic, meteoritic, and other theories. His investigations deal primarily with the David—de Boer Great Circle (77, 80). Since The Ivory Coast Tektites of Lacroix (106) and the Libyan Silica Glass of Spencer (104) both

[1] A curious statement is made as a footnote to La Paz's paper (122), to the effect that "Tektites are exhibited occasionally in placer mining camps in the United States. However, it is the author's experience that persistent questioning discloses always that such specimens come originally from the tektite-sprinkled goldfields of Australia." There may be some association between this fact and the Australian goldfield superstition that where tektites abounded the gold was richer.

lie outside that Circle, he postulates a second, the Lacroix-Spencer Great Circle, and suggests that further discoveries of the alignment of tektite areas and meteorite craters might thereon be anticipated.

The theory of a burning light-metal meteorite, shedding blobs of contained siliceous material, was put forward and elaborated by Lacroix (88), and Suess (87), having been developed from the somewhat different cosmic theories of Goldschmidt (74) and Michel (75). This hypothesis overcomes many difficulties of age, composition, distribution, and form that were not reconcilable with terrestrial theories, and may be regarded as being at present the most acceptable that has been put forward. Hardcastle (76) produced a very interesting theory on somewhat similar lines.

Even with the acceptance of a cosmic theory of origin there still remains considerable doubt as to the precise manner in which the tektites were brought to the earth, were melted, and were distributed. Most of the references published since 1900, 94 of which are given in the attached bibliography, are either descriptive of the properties and distribution of different groups, or are efforts to more clearly define an acceptable cosmic theory for the tektites as a whole.

III ADDITIONAL FACTS CONCERNING THE DISTRIBUTION OF AUSTRALITES

In a previous paper (103, pp. 127-8) examples were given to show how widely and generally australites were distributed. On the accepted figures, there must have been at least one to every two square miles, and while in some areas they are much more abundant (*vide* Dodwell's collection of 250 pieces on one square mile), it seems possible that there are few regions within the known strewn-field where australites did not fall.

Two interesting examples should be added to those already quoted, one reported from a locality near Port Campbell, Victoria, and the other from near Moonta, South Australia. Neither of these places, so far as I know, had hitherto been recorded as australite localities.

In 1936 George Baker published a paper (115) telling how he had collected, near Port Campbell, a representative series of 83 tektites, spread over an area of three square miles, mostly resting on the surface. Like most specimens found by "collectors," as contrasted with those found by gold miners or tin-miners, the pieces were relatively fresh and unweathered in appearance. Later, Mr. Baker found 52 additional specimens on the same area. [A further account by Mr. Baker states that he has since increased his finds to 250 specimens, all of them to the east of Port Campbell, and none to the west, *vide* "Walkabout," July, 1938, p. 36.]

The Moonta area in South Australia was equally unsuspected for the presence of australites until Mr. J. E. Johnson commenced to take an interest in these objects. He commenced his search among the Moonta sand-dunes, adjoining the coast of Spencer Gulf. He found one in July, 1937. Since then, in less than a year, he has found 72 pieces. It should be mentioned that these dunes were the sites of aboriginal camps. Australites are known to have been used by these people, both for magic purposes, and as material for cutting-tools. Mr. Johnson is of the opinion that many of the specimens collected had not been carried by the blacks. Most of the pieces were found exposed after wind storms, and the whole area where they were collected was but a few acres in extent.

These two instances support the examples already published as evidence of the general distribution of australites throughout southern Australia, as indicated in the map of distribution (114); but they emphasise the fact that some localities are rich in specimens and others very poor.

IV NOTES ON SMOKE BOMBS FROM LOCOMOTIVE ENGINES

In a previous paper (103, p. 72) the writer has referred to the valuable information to be garnered from a study of the smoke bombs (also called slag bombs) ejected from the chimneys of locomotive engines.

By the courtesy of Mr. E. H. Shapter, of the South Australian Railways, the writer has been enabled to study this material further. Samples were obtained of the cinders deposited, *(a)* on the rear of the tender of a locomotive of the RX type, *(b)* on the front of the tender of a mountain type engine, 47 feet from the chimney, *(c)* on the rear of the tender of a mountain type engine, 73 feet from the chimney.

There proved to be no outstanding differences in the samples. In each case about 99 per cent. of the material collected consists of cellular coke fragments, etc., and about one per cent. (by bulk) of the beautifully-shaped and many-coloured tiny glassy blobs that show regular forms. Sample *(b)* naturally contained more large specimens than sample *(c)*, but the richest in these bead-like forms was that from the RX engine, sample *(a)*.

The separation of the material is easily carried out, first by running water which takes off the lighter coke fragments, and then by a cautious "panning off" process similar to that of the alluvial (placer) gold-miner. The photographs shown in pl. x illustrate a sample obtained in this way, as well as selected specimens of the oval, dumbbell, and teardrop types.

As the photographs show, the dominant forms are very beautiful and almost perfect spheres, perhaps eighty per cent. of the total. These are of various colours: dead black, china white, amber, green, yellow, etc. Some of them are tubercled, by the attachment of smaller spheres, and many of them contain gas bubbles, both spherical and drawn out. Ovals and flat discs are fairly common, and the dumbbells and teardrops least common; the more fragile teardrops and dumbbells are easily broken by rough treatment of the sample.

The microscopic examination of smoke bombs is a matter of exceptional fascination. Despite the limitations of form and colour, already mentioned, there is remarkable variety and beauty to be found. The forms vary considerably in size. The largest I have seen, a veritable "giant," almost a hand specimen among these tiny forms, was a flattened spheroid, the greater diameter of which was one millimetre. Below this there are forms of all sizes, and as one increases the magnification, particularly by micro-photography, smaller and smaller forms appear, quite perfect in shape, among the particles of fine dust that accompany the material.

Similar forms to these smoke bombs have been recorded from volcanic sources, as well as from the sites of meteoritic impact. Moore (65) records some among Pele's tears from Hawaii, while Spencer (91) figures related shapes from Henbury and Wabar. In both cases the objects are similar to smoke bombs, not having suffered any subsequent ablation, as the australites have done. The dumbbell forms figured from Billiton (48) and Java (108) appear also to be quite similar to forms found among smoke bombs.

The significant facts to be considered in connection with the bearing of smoke bombs on the australite problem are: *(a)* the remarkable similarity of the chief form-types to those of australites, and the relative abundance of each type; *(b)* the fact that while smoke bombs and australites seem to be so much alike, there is not one form among the slag bombs which is exactly paralleled among the australites. That is to say: each australite has undergone some secondary alteration of form.

The suggestion is inevitable that both series were born from burning material that contained a proportion of siliceous glass, and that blobs of incombustible silica glass were generated, instantly attaining their primitive forms of sphere, oval, dumbbell, and teardrop, the first-named of the series being by far the commonest.

The smoke bombs, however, entered cold air just beyond the engine chimney, and consequently cooled and fell. The australites, born under conditions that gave rise to much larger forms, some thousands of times larger, sped through the air on their spinning flight, wearing by ablation, and thus taking on the secondary forms that are characteristic of the australites, which are reduced in size and "flattened' compared with the smoke bombs (see pl. xi).

This evidence for the dominance of the sphere among the smoke bombs, combined with the abundance of "round" forms among the australites, is an important part of the foundation upon which is based the discussion contained in Section VI. The photographs shown in the accompanying plates support the evidence brought forward in this section.

V. THE POSSIBLE EVOLUTION OF VARIOUS TYPICAL AUSTRALITE FORMS

In 1934 the writer advanced a theory (ref. 103, p. 132) that all the "round" australite forms *(i.e.,* round in plan) had been developed from spheres. Effort will be made here to elaborate that theory.

(a) Origin of the Glass Blobs—There was a time in the early stages of development of the cosmic theory when a belief was held that the tektites had them-

selves entered the atmosphere from outside space as a swarm of glass blobs. Speculation was even made as to the cosmic or lunar origin of such blobs. But Fletcher Watson (107), Ernst Opik (121), and others have shown that the amount of heat that could be generated by the passage of such bodies through the air, considered in conjunction with the heat conductivity of the material, is not sufficient to melt them to the extent that they obviously have been melted during the period immediately preceding their arrival on the earth's surface.

It is clear, therefore, that whatever the actual mode of origin may have been, it involved the generation of these blobs *within* the atmosphere in a molten condition, with their instantaneous adoption of the regular forms of spheres, ovoids, dumbbells, etc. The two sets of internal flow lines, one set associated with the original spherical form, and one set associated with the frontal melting and flow, are clearly to be seen in the sections shown in plate xi.

We are compelled to assume that, whatever their origin, the spheres of silica glass set out upon their short, swift journey through the atmosphere as molten bodies. Moving through the upper air, rotating in a plane normal to the direction of flight (ref. 121, p. 36), the front and sides of each sphere would be re heated by friction, while the rearward surface would cool. At the rear of each flying sphere would be a space of low pressure and low temperature. The fused material from the front of the sphere would flow backwards round the body of the object, evaporating or being swept away, but in special cases adhering to the circumference of the diminishing sphere, forming the "flange" of the well-known "button" forms (see sections, pl. xi). During the last portion of the flight the mass would rapidly cool, after the manner of meteorites generally, arriving on the surface of the earth as a solid glassy body. Both internal and external evidence supports this general hypothesis.

(b) Predominance of Round Forms—The predominance of round forms among australites is notable. In the Shaw collection (103) there were 1,993 perfectly preserved specimens; of these no less than 1,369 (over 68 per cent.) were round; among the 1,583 fragments in that collection, over 60 per cent. were derived from round forms. Inspection of other collections of australites confirms this proportion. It may be significant also, as shown elsewhere in this paper, that the great majority of silica-glass blobs (smoke bombs) formed in the chimney gases of locomotives are spheres.

The evolution of the various australite forms is here being considered purely from the evidence available from "round" forms, for the following reasons:

(i) round forms (lenses, buttons, cores, bungs) predominate to the extent of two-thirds of all forms;

(ii) round forms present the most definite and clear-cut material upon which to carry out a series of measurements; and

(iii) since the remaining forms (ovals, boats, dumbbells, teardrops) are generally accepted as being derived from the round forms, the conclusions based on a study of the round forms could readily be applied to the others.

There is a very small number of rare aberrant forms that would perhaps justify special enquiry, such as those known as large bubbles, air-bombs, peanuts, coins, pine-seeds, and crinkly-tops; all these can, I think, be explained as examples of variation from the more common types.

(c) Characteristics of Round Forms—Careful examination and measurement of a considerable number of the round forms of australites leaves one with a clear impression of several characteristics:

(i) The general outline of complete forms is bounded by two main surfaces, each of which is part of a sphere; this has been noted by several observers from Walcott (30) onwards. (See also pls. x and xi);

(ii) there is a general harmonious relation between the major diameter (width) of such australites and the minor diameter (depth); for instance, the writer's first effort to establish this connection suggested that the relation in flanged buttons (neglecting the flange in the measurement) could be expressed by a ratio of 16 to 10, while the ratio for lenses averaged 24 to 10. This approximate result was sufficiently encouraging to justify a more complete series of measurements.;

(iii) there seemed indeed to be a third general fact concerning the sizes of these forms. The largest were always of the large core ("bung") type, the smallest were always lenses, while the flanged buttons were always of intermediate size between these two series;

(iv) finally, there was the question of number. Bungs were not only the largest of the round forms, but also the rarest, while lenses were not only the smallest, but also the most abundant. In the Shaw collection, 80 per cent. of the round forms were lenses. Possibly 50 per cent. of all australite forms are or were lenses.

(d) Graph of Diameter Ratios—It was decided to investigate these points by measurement of a number of the most perfect specimens of the round types available. From the South Australian Museum collection (including the Shaw collection), by the courtesy of Sir Douglas Mawson and the Director, Mr. H. M. Hale, and from my own specimens, the following were selected:

1. Thirty-eight large cores (bungs), being every complete specimen available;
2. Twenty-seven small cores, being all the specimens of this type of which reliable measurements could be made; these forms are relatively common, but have a characteristic strong tendency to flake away at their margins;
3. Forty-two flanged buttons, all the specimens available (the width of flange neglected in the measurements);
4. Eighty-two lenses, being a selection of the different sizes from the largest to the smallest.

In the case of the lenses, however, so abundant are they that another 800 forms were available for measurement, but were not considered necessary. The remarkable preponderance of the lens type will be recalled later as evidence concerning the development of australite forms.

The range of measurements was as follows:

	Major Diameter	Minor Diameter
(i) Bungs, largest - - -	4·18 cm.	3·34 cm.
,, smallest - - -	2·12 ,,	1·58 ,,
(ii) Small cores, largest - -	2·30 ,,	1·70 ,,
,, ,, smallest - -	1·63 ,,	1·11 ,,
(iii) Buttons, largest - - -	1·93 ,,	1·12 ,,
,, smallest - - -	1·28 ,,	·73 ,,
(iv) Lenses, largest - - -	1·60 ,,	1·00 ,,
,, smallest - - -	·60 ,,	·30 ,,

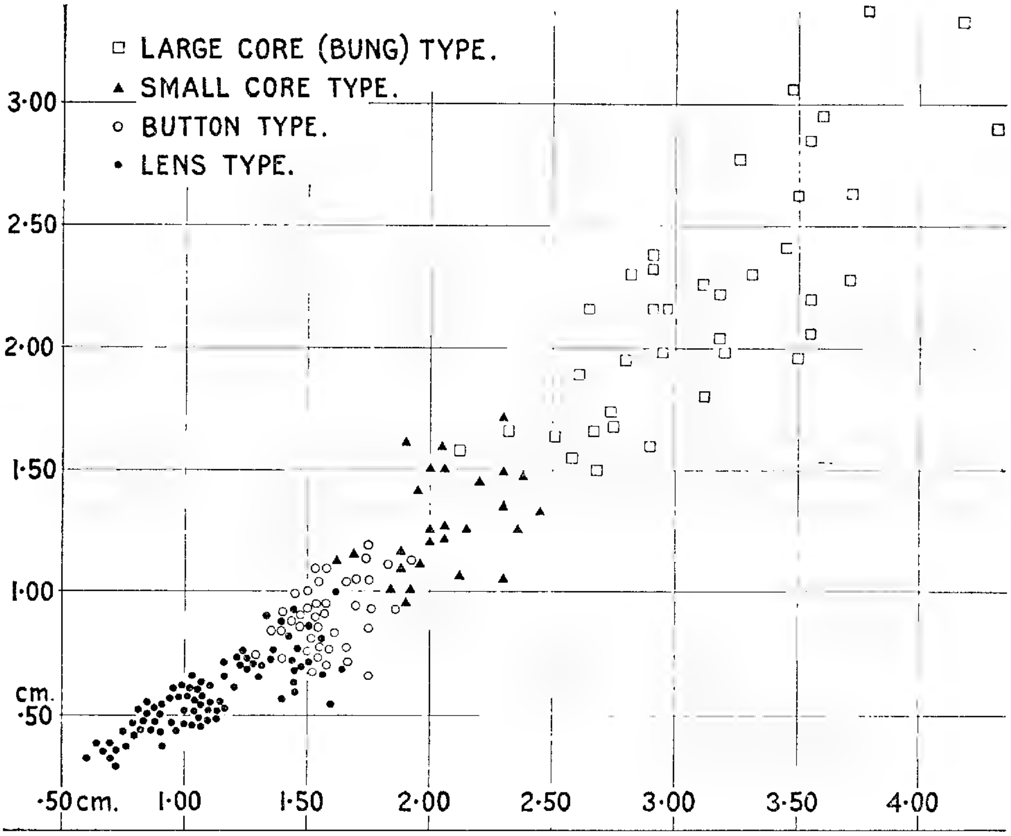

Fig. 1

Graph showing the ratio of major diameters (width) to minor diameters (thickness) of 189 selected well-preserved round australite forms. These ranged from the smallest lenses, through the buttons and small cores, to the largest type, called bungs. The smallest lens approaches one-third gram in weight, the largest bung is over 100 grams; this embraces almost the whole range of sizes. The ratios preserve a remarkable and significant relation to the forms, and to the relative sizes of these forms, and suggests an evolutionary development from spheres, through bungs, small cores, flanged buttons, and lenses.

Upon graphing the whole of these measurements, major diameters against minor diameters, there emerged the very interesting arrangement shown in fig. 1. It will be seen that the graph bears witness to the truth of the generalization suggested earlier in this section concerning the progressive development from sphere to lens, and it also suggests a great deal more concerning the probable mode of development of round australite forms.

The graph indicates that throughout the whole series of forms a general ratio of measurements is preserved, and that this ratio tends to become greater as we move downward from the larger "bungs" to the smaller "lenses". The relative evenness and unbrokenness of the series, as testified by the graph, suggests that the specimens available were representative of all the various sizes and types that occur. There is, moreover, a striking suggestion of an evolutionary progress in the way the bungs merge into the smaller cores, the latter into the buttons, and these in turn into the extremely abundant final product, the lenses.

(c) Suggested Evolution of Round Forms—Starting from the assumption that all these "round" forms were developed from spheres, and this is practically undoubted, we may further develop the series of events suggested by the actual australite forms and supported by the graph.

The preliminary evidence for the assumption of spheres as the starting point of all the round forms is:

(i) The abundance of spheres among smoke bombs;

(ii) the spherical nature of the remaining "rear" surfaces of round australites;

(iii) the evidence of the graph, which suggests an approach to a 1 : 1 ratio at a diameter of about 5½ centimeters (see fig. 3).

In figure 2 is set out a series of six progressive stages, intended to represent the evolution of the commonest and best known of the australite forms. These are to be correlated with the graph, figure 1.

Stage 1 represents the original glass sphere. Whether shed from a burning light-metal meteorite (Lacroix, 84; Suess, 87), or swept from the sides of some more common cometary visitor (Michel, 75; Hardcastle, 76), or shot out from some other hot siliceous centre, these spherical forms took their shape at the instant of their separation from the parent body. From the known facts concerning the temperatures and the fusion of meteorites, these spheres must have commenced their journey through our atmosphere from somewhere less than 70 miles above the earth, at a temperature close to their melting point. On account of atmospheric ablation none of these spheres, as such, reached the earth's surface.

Stage 2 represents the development after perhaps one or two seconds of atmospheric flight. The "back" (upper) surface is often pitted by the bursting of small gas bubbles that came to the surface in that low pressure area. The "front" (lower) surface has re-melted under the heat generated by atmospheric friction, some part of this material has flowed backwards along the sides of the sphere, and a considerable part of the front and sides of the material within the sphere itself has re-melted and developed "strain" lines. (See also pl. xi.) With the rapid cooling of the hotter portions of the bodies that reached the earth while at this stage an unstable condition of the glass resulted, so that they tended to lose much of their material by cracking and flaking, leaving the more stable portion, the centre and back (that had cooled less quickly), to be preserved in the characteristic shape known as the bung (see the upper dotted line in stage 2). This is the general shape of all the larger round unworn australites.

Stage 3 represents the next development, no more than a progressive ablation and back-flowing of the material in the front of the spinning blob. The facts

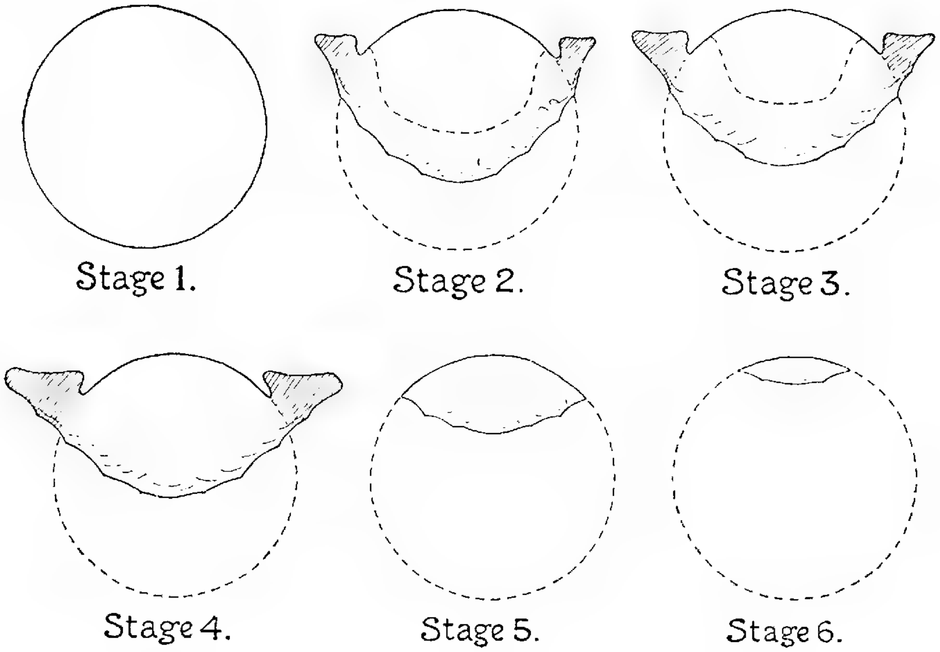

Fig. 2

Sketches of cross-sections of a series of six stages in the development of australites. Stage 1 (the sphere) is hypothetical, but it cannot be doubted that it was the initial form in the great majority of cases. Stages 2 and 3 are hypothetical in part, being drawn to represent the probable shapes between stages 1 and 4; but the central more stable portions of these forms are well known, that of stage 2 as the bung, and that of stage 3 as the small core. Stages 4, 5, and 6 are representations of actual common forms. The sketches should be correlated with figure 1, and compared with the photographs in plates x and xi.

suggest that at this stage there is an even more marked instability of the "equatorial" portions, so that cracking and flaking of the solid specimens are more common, and from this stage we get the smaller cores. These, though they have usually well-preserved back (upper) surfaces, are much more deeply and more irregularly flaked on their sides and fronts than any other australite forms. The shape of the cores at this stage is suggested by the upper dotted line. The assumption in the figures of a flange for stages 2 and 3 is pure speculation, based on analogy with the flanged button (stage 4). Stages 2 and 3 may have had no flanges at all: there is no positive evidence available. Indeed, the evidence quoted in reference 112, pages 130-131, suggests that in some cases at least there was no flange present in the large cores and bungs.

There is clear evidence in the transition from flanged button to unflanged lens, to prove that the backward-flowing melted material did not as a rule proceed beyond a certain line. Here apparently the molten material was affected by the probable intense cold of the sheltered rear low-pressure zone, so that the glass material solidified. As later suggested, there may have been some exceptional cases where the conditions permitted material to flow farther back.

Opik (reference 121, page 47), speaking of the liquid that flows backward from the front and sides of a speeding meteorite, remarks that it "is collected in the portions less exposed to aerodynamic pressure (rear side, especially rear pole of rotation)." This may be so for meteoritic irons or stones, but it is clearly not so in the case of glassy blobs, as witnessed by the external form of the flanged buttons (pl. x), and more definitely by the photographs of thin sections of buttons (pl. xi).

Stage 4 represents an actual, characteristic cross-section of a flanged button. At this stage more than half the material of the sphere has disappeared. It is only at or before this stage that the conditions permit of the development of the beautiful flange that forms the most arresting feature of the button type. At earlier stages this material was either swept away or has flaked off; at later stages (5 and 6) only the rear portion of the sphere is preserved, as a lens.[2] It is at this stage that a more stable condition of the whole mass is reached, and though flaking and fracturing due to internal tension are testified to by numberless button fragments, there are still numbers of flanged buttons perfectly preserved, while all such larger forms as cores and bungs are invariably diminished by flaking. Flanged buttons are the largest forms that preserve the regular waves of flow upon their forward surfaces.

Stages 5 and 6. These are two successive stages in the final development of the round forms. Thus are formed the lenses, larger and smaller. The largest lenses have major diameters that are just equal to the zone beyond which the backward-flowing glass of the flange did not normally advance.

The smallest known lenses are so tiny that only the acute vision of the aborigines would ever have detected them among the sands and rubble that cover the earth's surface where most of them were picked up. Doubtless there were smaller lenses that have never been found, or that have been too fragile to resist fracture. Doubtless also many spheres went beyond this stage of development during their journey, being completely consumed. Eighty per cent. of all the

(2) There are a few rare examples of australites in which the backward-flowing material appears to have advanced beyond the points shown in stages 2, 3, and 4 of figure 2. Among these I would place the "crinkly tops" (ref. 103, type A2g, 69, pl. ix F) and the curious forms figured by Dunn (ref. 67, pl. xxiii).

original spheres were ablated down to the lens stage, so far as the evidence of the Shaw collection is concerned.

(f) Relations of Forms and Sizes—Some natural speculations follow this analysis. If all the original spheres had been of the same size, of the same temperature, composition, and speed, and had the same distance to travel through the air, there would have been one similar type of final product: lens, button, core, as the case may be.

We know them to have had approximately the same chemical composition. It is reasonable to assume equal temperatures within certain limits. Measurements of the residual spherical surfaces show, however, that the primary spheres were of many sizes, up to about five centimetres diameter. The chief causes of the difference in the stages at which these glass spheres reached the earth, it is suggested, were variations in the distances travelled, and in the speed of travel, both of which factors must have varied according to the direction in which the objects moved relative to the earth's surface and to the moving body from the surface of which they are presumed to have been swept. We must remember, also, that the parent meteorite was probably rotating, thus giving a variety of speeds and directions to the glass blobs.

A special effort was made to determine the actual sizes of the original spheres of the five separate australites shown in plate x. These proved to be as follows, and give some idea of the actual range of sizes of the original spheres:

(i)	The bung type - - - -	4·7	mm. diameter
(ii)	The core type - - - -	3·1	,, ,,
(iii)	The button type - - -	1·6	,, ,,
(iv)	The large lens type - - -	1·7	,, ,,
(v)	The small lens type - - -	1·0	,, ,,

These measurements correspond with and support the theories elsewhere put forward in this paper concerning the spherical origin of "round" australites, and also the range of sizes. The original glass sphere from which the "bung" was derived was somewhat over 100 times as large as the original sphere that resulted in the "small lens." It will be noted also that, although the button looks larger than the lens (pl. x), on account of the flange, it was actually derived from a somewhat smaller original sphere.

In figure 3, curves A and B, there appear to be two conclusions which support each other. Though arrived at from a basis of fact, the conclusions are equally hypothetical. In A, a median curve, drawn from the data of figure 1, is continued upwards; the sphere type is found (ratio of diameters 1:1) at about $5\frac{1}{2}$ cm. This may be interpreted to mean that the largest original spheres were of this size. The graph confirms the harmonious relations that suggest the development from spheres of the forms measured, but is valuable more for its suggestiveness than for any definite numerical implication; the value of the upper part of the curve is lessened by the fact that the measurements are of specimens that had undergone flaking since their formation.

In the second curve, figure 3 B, the numbers of specimens are set out in groups according to size. First group, up to 1 cm. diameter; second group, 1 to 2 cm. diameter; and so on. The latter part of the curve is quite clear, and indicates the rapid decrease in numbers of the larger specimens, with a suggestion that there were few or no specimens larger than 5½ cm. diameter.

In the first part of curve B, however, there is some uncertainty. The actual numbers of the smallest group are less than those of the second group. But there is reason to believe that there may actually be much higher numbers of the small specimens, most of which have not been found owing to their size or have been destroyed because of their fragility. The part of the curve marked Q is based

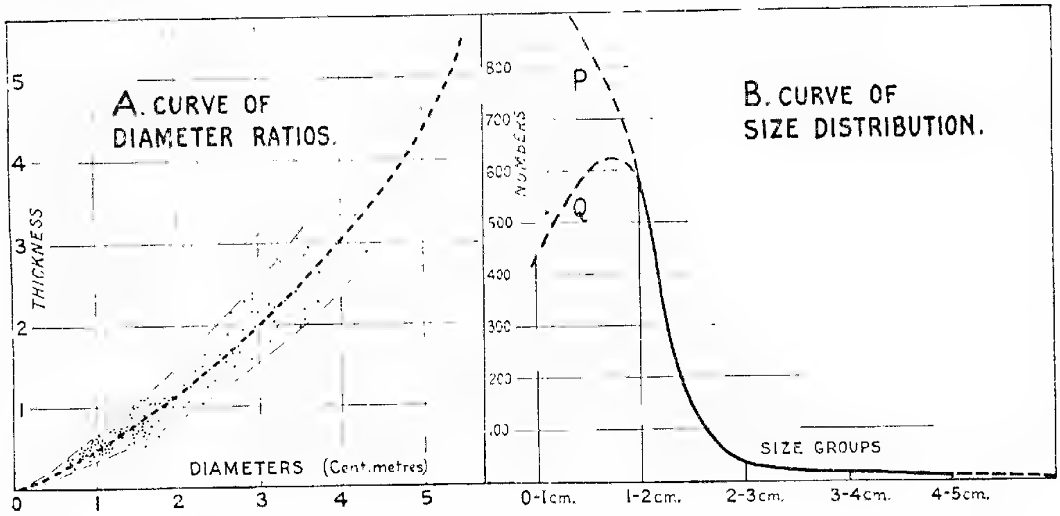

Fig. 3

A (left side) is based on the same information as is contained in fig. 1, but the probable curve represented is shown, and is continued to a point where the ratio of diameters is 1: 1.

B (right side) is a curve of size distribution of australites based on the specimens available for measurement. It indicates the overwhelming abundance of specimens under two centimetres major diameters, and the probability that there are no specimens much above 5½ centimetres diameter.

on the known facts of collected specimens, and agrees with the graph of weight-distribution given previously (reference 103, page 78). The part of the curve marked P is an alternative interpretation, suggesting that the great majority of forms were very small and remain uncollected.

(g) Comparison with the Stony Meteorites—An idea of the possible manner of the shedding of the glass blobs may be gained from a microscope study of the fused surface of a stony meteorite. There the thin skin of fused vitreous residue has the appearance of a series of irregular waves and wrinkles. In places the material is arranged in long sub-parallel wave-like ridges, probably formed at right angles to the direction of movement. The ridges rise higher at some

points than at others, and one could imagine the "knobs" or crests becoming large enough to be swept off from the meteorite surface as independent blobs.

(h) Conclusions—Summing up the evidence of this section we have these tentative conclusions:

(i) most of the original australite blobs were spheres;
(ii) during their spinning flight they were reduced in size in a regular way, developing ultimately to the button and then to the lens stages;
(iii) a small percentage never developed beyond stages 2 and 3;
(iv) somewhat more than 5 per cent. reached the stage of flanged buttons;
(v) the majority (80%) remained in the air long enough to be ablated away to stages 5 and 6, the lenses.
(vi) possibly others were completely evaporated during flight.

VI SPECULATIONS CONCERNING THE THEORY OF COSMIC ORIGIN

Every theory of terrestrial origin that man's ingenuity has been able to put forward during 150 years of discussion having now been elaborated, discussed, and for the most part rejected, there remains the theory (or theories) of cosmic origin.

Many workers, themselves inclined by the facts of their experience towards the cosmic theory, have expressed an opinion that the only method of proving this theory would be the witnessing by man of an actual shower of glass meteorites. That would indeed be an excellent confirmation, devoutly to be wished, but it is unlikely. Meantime, other workers are steadily moving onward, selecting fresh criteria, and endeavouring to discover positive evidence to prove from the available material that tektites are of cosmic origin.

Even if we accept the meteoritic or cosmic theory, on the grounds that it is the only one that satisfies all the known conditions, we are still far away from an ultimate solution of the problem.

Let us take, for example, the most popular of the cosmic theories that have lately been entertained and discussed, namely, that of a burning, light-metal meteorite (or a "swarm" of such meteorites) passing above the earth and shedding its content of silicous material in small glassy blobs. We may endeavour to apply this theory to the australite problem, but it seems clear, from the numerical facts, that we must postulate a swarm of meteorites, and not a single meteorite.

The strewnfield of the australites (114, page 134) covers over 2,000,000 square miles of land; it is over 2,000 miles from south-east to north-west, and about 1,500 miles in width. It is generally agreed that the "shower" travelled from south-east to north-west, though there is no actual evidence that it did so; the direction of travel might even have been at right angles to this.

In the case of the moldavites there is a narrowing of the strewnfield from west to east, as well as an accompanying change in physical characters (125). With the australites, Summers (52) suggested that there was a variation in density towards the west, and Hardcastle (76) stated that more of the larger forms fell towards the west. But these suggestions have not been followed up, and there is no extensive evidence of appreciable difference in average composition, density, or size across the area.

We may first try to form a mental picture of a meteorite swarm travelling for over 2,000 miles through the air, relatively close to the earth's surface (within 70 or 80 miles), and continuing to burn throughout the passage. This brings up questions of speed, path, weight, friction, heat, and so on, as well as of the manner in which the glass blobs were swept off the parent body. First, we shall consider temperatures and conductivity.

In considering these aspects of the problem I have had the privilege of many discussions with Mr. G. F. Dodwell, B.A., Government Astronomer of South Australia, and he has kindly supplied the following statement, with permission for its inclusion here:

"The mechanics of meteor phenomena are not easy. Opik, of Tartu Observatory (Esthonia), has a very interesting and long paper on it, containing a great deal of helpful information and calculation (ref. 121). In his Table VI he gives the characteristics of fusion for a stony meteorite. In this, R is taken as the radius of the solid nucleus, $\triangle$ R the effective thickness of the liquid layer (a liquid surface condition being the result of friction in the earth's atmosphere), T is absolute temperature, $\triangle$ T is the temperature difference between the surface of the liquid film, and the bottom of the film (taken as constant at 1800°, the temperature of fusion, which, he says, is effectively the same as for iron); M is the apparent stellar magnitude of the meteor, and W its velocity. The table then is:

	R = 1 cm.			R = 0·1 cm.			R = 0·02 cm.		
	$\triangle$ R	$\triangle$ T	M	$\triangle$ R	$\triangle$ T	M	$\triangle$ R	$\triangle$ T	M
W.	Cm.			Cm.			Cm.		
16 Km./Sec.	0·035	(24,000°)	–1	0·011	800°	7	0·005	70°	13
40 ,, ,,	0·054	(92,000°)	–5	0·017	(3,100°)	5	(0·008)	270°	10
90 ,, ,,	0·081	(320,000°)	–9	0·026	(10,000°)	2	(0·012)	870°	7

"We might take 1 centimeter radius as representing a medium-sized australite. Then for R = 1 cm. the values of $\triangle$ T are enormous; this means that the layer never reaches the computed thickness $\triangle$ R, but starts boiling when its thickness is of the order of $\triangle R \times \frac{1{,}000}{\triangle T}$; such a thin layer sticks to the surface by reason of viscosity.

"Thus for R = 1 cm. the substance of the nucleus is practically vaporized, so to speak, on the spot, the thickness of the liquid layer being of the order of 0·001 cm. only; most of the solid nucleus remains cold inside. This case evidently resembles the phenomena observed in large metorites reaching the ground.

"Opik concludes that stone meteors brighter than the seventh apparent magnitude are vaporized from the surface of a thin liquid layer, the nucleus remaining solid. This agrees with what Nininger says in 'Our Stone-pelted Planet,' page 29, where he gives his belief that owing to the brief flight of a meteorite through the air, only a few seconds (in general 3 to 6 seconds), the surface heat for ordinary-sized meteorites is unable to penetrate into the interior, which remains cold. On page 89 he says that the enveloping crust of fused material is, in most cases, about five-tenths of a millimeter in thickness. This molten film is being constantly swept off and dissipated by currents of air sweeping across the face of the meteorite at the rate of several miles per second. On page 89, also, he gives the upper limit of visible meteors as approximately 70 miles above the earth.

"On page 24 he gives the average heliocentric velocity of meteorites as 26·2 miles per second. As the earth's velocity is 18·5 miles per second, this gives the range of velocity of meteorites, according as they are travelling with or against the earth's direction, 26·2 — 18·5 = 7·7 miles per second, up to 26·2 + 18·5 = 44·7 miles per second. This agrees with the data in the Von Niessl-Hoffmeister Catalogue of 611 great meteors, and analysed by Maltzev. The range of geocentric velocities is given there as from 6 to 43 miles per second (Popular Astronomy, April, 1937, 213).

"In view of Opik's calculations, it seems to me difficult to reconcile the occurrence of australites with the disintegration of a large meteorite, weighing many tons, and travelling over the required distance. Is it possible for such a large meteorite to travel such a distance, say 3,000 miles, at only 70 miles or less from the surface of the Earth, without being drawn in by gravitation within a small fraction of that distance? Examining this with reference to say an 8-inch globe, the moving body, reduced to scale of the model, would have to traverse a circular path, parallel to the globe and only one-tenth of an inch above it! On the other hand, of course, one thinks of the exceptional case of the 'great meteorite procession of 9 February, 1913.' (See P. Astr., Feb., 1938, 109.)"

Nininger's reference to the meteorite procession of 9 February, 1913 ("Our Stone-pelted Planet," pages 85-86) includes the following: "This great procession of meteors was witnessed along a course of 5,700 miles. It consisted of six to ten groups of fireballs, four to six in each group. They proceeded across Canada, to the south-east, growing more brilliant as they went; they seem to have plunged into the sea somewhere south-east of the Bermudas." C. P. Olivier ("Meteors," page 242) says that the procession seems to have consisted of "ten groups, with 20 to 40 members in each group. In Canada it is said to have taken 3·3 minutes to pass a given place." See also La Paz (122, page 227).

We see, then, that the track of the hypothetical australite meteor swarm, so far as distance is concerned, is within the bounds of what a meteorite group has actually been observed to do.

We have now to account for the width of the area over which the blobs have been scattered. This, as already stated, is about 1,500 miles. We may assume, as is commonly done, that the australite shower was derived from a group of meteorites travelling from the south-east to the north-west. The problem is somewhat similar whatever direction we assume. If, however, the direction were from south-east to north-west, the period of travel across the strewnfield would possibly occupy no more than 45 seconds; if from north-west to south-east, this period would be nearer five minutes.

It must perhaps be emphasised, for the information of those unfamiliar with the strewnfield of the australites, that there can be no doubt that their widespread distribution is associated with the manner of their coming. It is not something done subsequently either by man, or birds, or winds, or glaciers. All these theories have been advanced and rejected. When the australites arrived at the surface of the earth they were spread over the area shown, approximately, in the map on page 134 of part II of this series of papers.

This means that the hypothetical parent meteorite swarm, something less than 70 to 80 miles above the earth, travelling at from eight to forty-five miles per second, according to direction, must have flung blobs of glass, broadcast fashion, over 750 miles to either side. There was nothing comparable to this in the Great Meteorite Procession of Canada. Nininger says, "Detonations and earth tremors were caused along their pathway to a distance of 20 to 70 miles on either side." So far as we know, no actual blobs were shed from these meteorites, and the observations suggest a very narrow range of influence. We must recall, however, that this was a meteoritic "procession," presumably a long line, one behind the other; we may conceive a meteorite swarm that moved with a wide and irregular front.

In order that we may better discuss the problem of distribution, let us consider the question of the total size of our hypothetical meteor swarm. The total number of australites is estimated at from one to ten millions. The average weight per specimen is one gram, and the average weight for each original blob, say, three grams. This gives a total of from 3,000,000 to 30,000,000 grams, approximately, and involves a minimum of three tons of silica-glass up to a maximum of thirty tons.

There is no means of knowing with what amount of combustible metal this had been associated, but it may not be unreasonable to suggest the siliceous content at 10 per cent. This gives 30 to 300 tons of material in our meteor swarm. This is necessarily a very approximate and tentative estimate, just to give some definition to this aspect of the discussion.

It is difficult to form a satisfactory mental picture of this hypothetical meteor swarm, shedding its silica content across 750 miles on either side. Moreover, although there are possibly few parts of southern Australia that did not receive some of the australites, specimens are very rare over some areas and very abundant over others. The areas of abundance are not along the central axis of the strewnfield, nor in any regular arrangement.

So far as width is concerned the Leonid swarm of meteorites, in its most densely packed part, is from 100,000 to 120,000 miles in diameter (estimates by Sir Robert Ball and C. P. Olivier); there are also cometary bodies with comparable size. It is thus not inconceivable that the particular meteorite swarm that gave rise to the australites should have extended over a path some 1,000 miles or more in width, and we shall assume this to have been the case.

VII SUMMARY OF HYPOTHESIS

Following upon this account of the tektite problem, as viewed from a study of the australites, it may be worth while to formulate a specific hypothesis as a basis for further discussion.

The suggestion is therefore put forward that, in the case of the australites, at a time "geologically recent but historically remote," the earth was visited by a large and widespread swarm of combustible metallic meteorites. The swarm was not less than 30 tons, and possibly 300 tons, in total weight, containing (say) ten per cent. of siliceous material. The component bodies travelled across Australia in a wide and irregular formation on a front of 1,000 miles or more, at a height of 80 miles or less, burning as they went. Possibly some were burnt up relatively early, while others entered the atmosphere later and farther on. The period of transit of the swarm across Australia occupied at least 45 seconds and at the most five minutes. Their residual incombustible siliceous content was shed in molten glass blobs, these being for the most part swept backwards by the rush of air from the rotating parent bodies, and thence shot outward in many directions. The glassy blobs, to the number of from one to ten millions, averaging about three grams in weight, sped to the earth, rapidly rotating and undergoing ablation and flow from their forward parts, reaching the earth's surface in from three to six seconds, having been chilled to solidity during the last portion of their flight. The blobs, as they formed, instantly assumed the shapes of spheres and allied forms common to rotating liquid bodies, and these by ablation were reduced to the lens, button, and other form-types known as australites. They were thus distributed in an irregular way over the southern portion of the Australian continent.

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DESCRIPTION OF PLATES

PLATE X

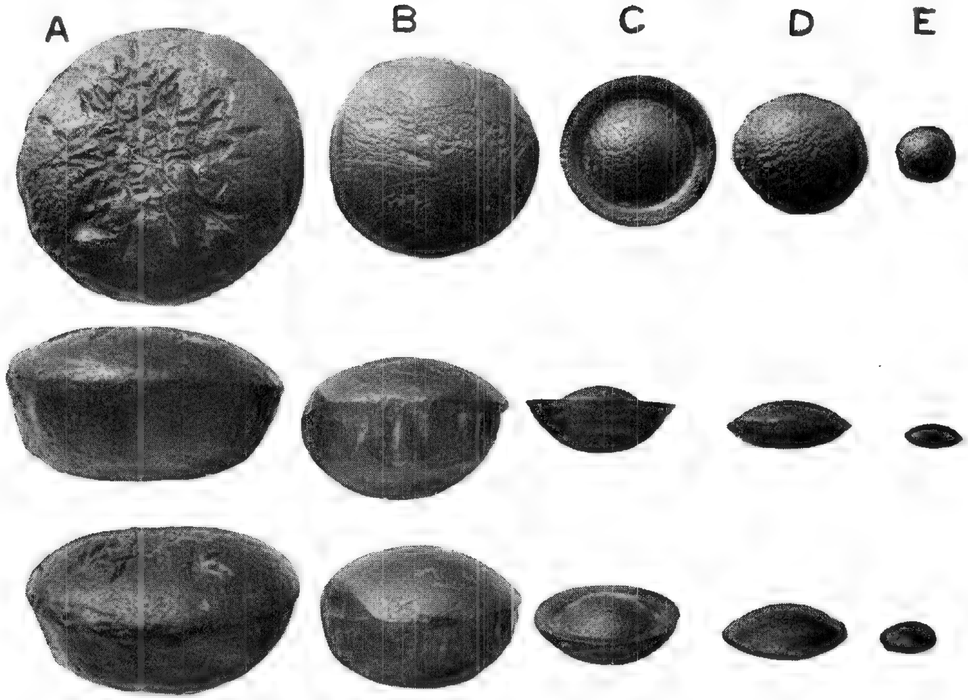
Upper: Three views of typical specimens of round australite forms: (a) bung, (b) small core, (c) button, (d) large lens, (e) small lens. The first row shows the top (rear) view, the second row shows a side view, and the third row shows an oblique view. These are the form-types dealt with in figures 1 and 2. (The largest specimen shows the sub-radial groovings that are found occasionally on the upper surfaces of the largest australites.)

Lower: Photograph of the characteristic types of smoke bombs. Spheres predominate in the material collected from railway engines, as shown in the photograph on the left side. In the right-hand photograph a selection has been made to show various less common forms that occur. The range of specimens in the latter photograph varies from one "giant" round form of 1 mm. diameter, down to a tiny specimen of bent dumb-bell type that was apparently blown on to the slide as a dust fragment; left side x 4; right side x 7. Microphotos: R. A. L. Laughton.

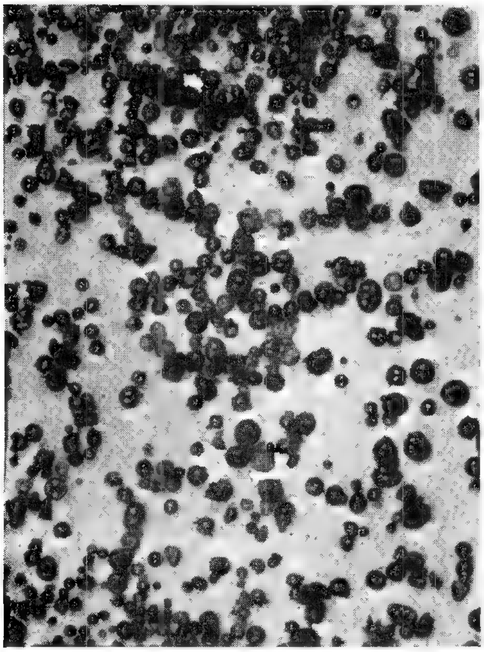
PLATE XI

Upper: Two photographs of thin median section of flanged buttons, x 4, reproduced from negatives made for E. J. Dunn, Bull. 27 (ref. 50), and lent by the Mines Department of Victoria. These photographs show the internal flow lines in two series, as postulated in this paper, and also show certain characteristics of the upper (rear) and lower (front) surfaces of australites. The secondary frontal melting and flow towards the equator into the flanges is well shown; in the lower specimen part of the flange has been lost and a new one is in process of formation.

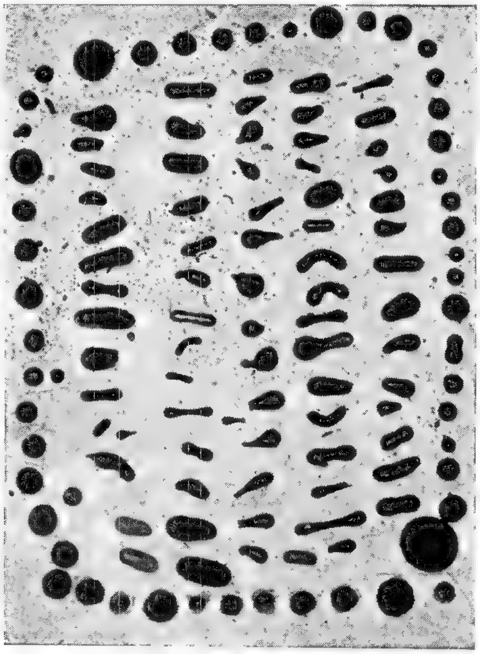
Lower: Magnifications of the smoke bomb (slag bomb) forms, x 20, to emphasise the differences between *(a)* the primary forms of the molten blobs, and *(b)* the ablated and diminished forms characteristic of australites, the latter x $\frac{3}{5}$. When seen "side on" the smoke bombs are the same as they appear from a top view; the side-on views of australites show the results of ablation and the development of flanges and rims.



Round Australite specimens
Top, side, and oblique views of bung, core, button, lens, and small lens types
Natural size



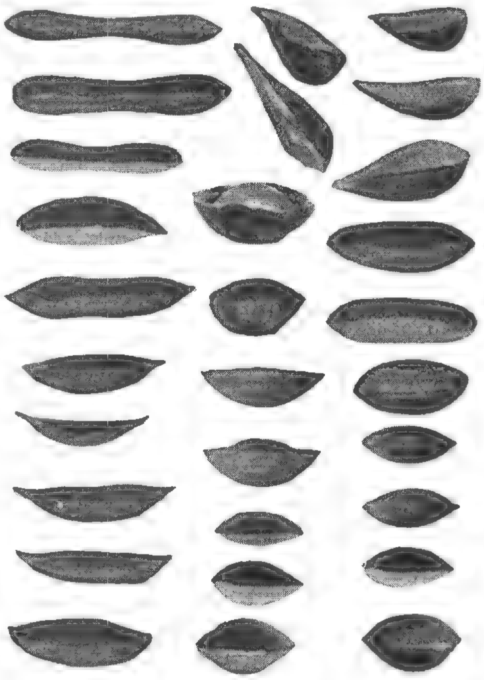
Smoke bombs. Average sample, x 4



Smoke bombs. Selected types, x 7

Median sections of flanged button types of Australite, x 4

Smoke bombs, x 20



Australites, x $\frac{2}{3}$

RECENT AND FOSSIL SPECIES OF THE SCAPHOPOD GENUS DENTALIUM IN SOUTHERN AUSTRALIA

BY B. C. COTTON AND NELLY HOOPER LUDBROOK, M.A.

Summary

I INTRODUCTION

Even a casual survey of the specimens of South Australian Scaphopoda, and of the literature upon them, reveals much confusion and haphazard identification of species. The following short account is, therefore, submitted as an attempt to point out discrepancies to those students who find difficulty in the correct naming of already known forms.

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[Read 14 July 1938]

Plate XII

Synopsis

I INTRODUCTION

Even a casual survey of the specimens of South Australian Scaphopoda, and of the literature upon them, reveals much confusion and haphazard identification of species. The following short account is, therefore, submitted as an attempt to point out discrepancies to those students who find difficulty in the correct naming of already known forms.

Both recent and fossil specimens have been examined, the latter chiefly from the Tate Museum, Adelaide University (including the Abattoirs Bore material), and the Commonwealth Palaeontological Collection at Canberra. The recent shells are well represented in the South Australian Museum in the Verco Collection, which has provided data for the elucidation of numerous errors in previous accounts of the Scaphopoda.

II RECENT SPECIES

The majority of the recent South Australian *Dentalium* species form a fairly distinctive subgenus, *Paradentalium* (subgenotype *D. bednalli* Pilsbry and Sharp, 1898), introduced for shells with six to fourteen intercalating ribs, usually continuing to the aperture or becoming obsolete, the intervals apparently smooth but microscopically concentrically and longitudinally striate; apex small; orifice simple, without terminal pipe, slit or notch.

In this subgenus can be included *D. bednalli*, *D. octopleuron*, *D. hemileuron*, *D. francisense*, *D. flindersi* sp. nov., and *D. tasmaniensis*.

In the second subgenus *Eudentalium* (genotype *D. quadricostatum* Brazier) Cotton and Godfrey, 1933, we place *D. beachportensis* sp. nov.; the subgenus being distinguished by the small, solid, square tube, serrate primary ribs and smooth interstices. The two species *D. bordaensis* sp. nov. and *D. hyperhemileuron* probably belong to the subgenus *Episiphon* Pilsbry and Sharp, while *D. verconis* sp. nov. and *D. jaffaensis* are placed in the subgenus *Fissidentalium* Fischer.

Class SCAPHOPODA

Family DENTALIIDAE

Genus Dentalium Linne, 1758

Subgenus Paradentalium Cotton and Godfrey, 1933

The South Australian recent species grouped under *Paradentalium* may be distinguished by the following key:

1 Ribs persistent through entire length of shell:
  (1) Interspaces wide, ribs 7-12:
    (a) Ribs 7, increasing to 10 .. .. *D. bednalli*
    (b) Ribs 12 .. .. *D. flindersi*
    (c) Ribs 8, remaining constant in number and size .. .. *D. octopleuron*
  (2) Interspaces linear, ribs 14 .. .. *D. franciscense*
2 Ribs obsolete or absent at the anterior end .. .. *D. hemileuron*

Dentalium bednalli Pilsbry and Sharp, 1898

D. bednalli Pilsbry and Sharp, 1898 Tryon's Man. Conch., **17**, 248, pl. xxxix, figs. 1-3; Cotton and Godfrey, 1933, S.A. Nat., **14**, (iv), 142

D. intercalatum Cotton and Godfrey, 1933 *id.*, 140, non Gould, 1859

D. decemcostatum Cotton and Godfrey, 1933 *id.*, 143, non Brazier, 1877

D. katowense Cotton and Godfrey, 1933 *id.*, 141, non Brazier, 1877

Type Locality—Gulf St. Vincent, S. Aust.

This is the correct name for the shell previously known in South Australia as *D. intercalatum*. Cotton and Godfrey, in introducing the subgenus *Paradentalium*, based it on the South Australian species *D. bednalli* Pilsbry and Sharp, but *D. intercalatum* Gould was quoted as genotype following Verco's incorrect identification of the South Australian shell. The South Australian species had already been described as *D. bednalli* Pilsbry and Sharp, and that was the species under discussion. The latter should now be regarded as the subgenotype.

D. katowense and *D. decemcostatum* have also been incorrectly used for some South Australian specimens of this species. The nearest allied species is *D. tasmaniensis* T. Woods (north-west coast of Tasmania) which has been recorded from Port Adelaide, but is not represented in our collection from South Australia. Subfossil specimens so named from the Port Adelaide River are somewhat intermediate between *D. bednalli* and *D. tasmaniensis;* mature specimens show the typical intercalate ribbing of the so-called South Australian "*intercalatum*.'

Dentalium flindersi sp. nov.

Pl. xii, fig. 4

D. duodecimcostatum Cotton and Godfrey, 1933 S.A. Nat., **14,** fig. 4, 141, non Brazier, 1877

Holotype—S.A. Mus. Coll. Reg. No. D. 13,338.

Shell medium size, solid, white, rather well curved towards the posterior; aperture regular and circular, displaying the twelve longitudinal ribs; apex fairly large, orifice small, oval, longer than wide, walls thick; sculpture of twelve narrow, rounded ribs, separated by deep, concave, decidedly wider intervals; ribs becoming wider anteriorly with a tendency to splitting by progressively deepening sulci, but not reaching the decidedly intercalate condition of *D. bednalli.*

Dimensions—Length, 21 mm.; breadth, 2·9 mm.

Recent. Flindersian, shallow water.

Type Locality—Gulf St. Vincent, 22 fathoms.

Observations—This is a shell previously listed from South Australia as *D. duodecimcostatum* Brazier (type locality, Darnley Island, Torres Strait, 30 fathoms), an entirely different species.

Dentalium octopleuron Verco, 1911

D. octogonum Angas, 1878 Proc. Zool. Soc., 868, non Lamarck

D. octopleuron Verco, 1911 Trans, Roy. Soc. S.A., **35,** 206; Cotton and Godfrey, 1933 S.A. Nat., **14,** (iv), 143

D. cheverti Cotton and Godfrey, 1933 *id.*, 141, non Pilsbry and Sharp

D. robustum Cotton and Godfrey, 1933 *id.*, 143, non Brazier.

D. thetidis Cotton and Godfrey, 1933 *id.*, 142, non Hedley

This species is closely related to *D. bednalli.* It was misnamed *D. octogonum* by Angas, and South Australian specimens labelled *D. cheverti, D. robustum, D. thetidis* are this species.

Recent, Flindersian, shallow water.

Dentalium tasmaniensis Tenison Woods, 1877

D. tasmaniensis T. Woods, 1877 Proci. Roy. Soc. Tas. for 1876, 140; Cotton and Godfrey, 1933 S.A. Nat., **14,** No. 4, 144

Type Locality—North-west coast of Tasmania.

Recent, Flindersian, Tasmania and Victoria only.

This species is allied to *D. bednalli* from South Australia; subfossils from the Port Adelaide River approach very closely to *D. tasmaniensis.*

Dentalium francisense Verco, 1911

D. francisense Verco, 1911 Trans. Roy Soc. S.A., **35,** 207, pl. xxxvi, figs. 1, 1a; Cotton and Godfrey, 1933 S.A. Nat., **14,** No. 4, 143, pl. i, figs. 1, 1a

Type Locality—Petrel Bay, Francis Island, S.A., 15-20 fathoms.
Recent, Flindersian, shallow water.

This species is also closely related to *D. bednalli.*

Dentalium hemileuron Verco, 1911

D. hemileuron Verco, 1911 Trans. Roy. Soc. S. Aust., **35**, 208, pl. xxxvi, fig. 2; Cotton and Godfrey, 1933 *loc cit.*, 144, pl. i, fig. 2

Type Locality—Cape Jaffa, 300 fathoms.

Recent, Flindersian, deep water.

Subgenus Eudentalium Cotton and Godfrey, 1933
(Genotype *D. quadricostatum* Brazier)

Dentalium beachportensis sp. nov.
Pl. xii, fig. 2

D. quadricostatum Cotton and Godfrey, 1933 *loc. cit.*, 145, non Brazier

Holotype—S.A. Mus. Coll., Reg. No. D. 13,339.

Shell almost square, opaque white, very slowly increasing, four-angled, with a wide, distinct rib at each angle; interstices sunken, obsoletely longitudinally striate; apparently the ribs are obsoletely serrated; apex perforated, narrow, entire; aperture square, narrow, peristome very thick. The unique specimen is broken and eroded, but it is apparently distinct from *D. quadricostatum.*

Dimensions—Length, 17 mm.; breadth, 2·5 mm.
Recent, Flindersian, deep water.

Type Locality—Beachport, S.A., 110 fathoms.

Subgenus Episiphon Pilsbry and Sharp, 1897
(Genotype *D. sowerbyi* Guilding)

Dentalium bordaensis sp. nov.
Pl. xii, fig. 3

D. virgula Cotton and Godfrey, 1933 *loc. cit.*, 145, non Hedley

Holotype—S.A. Mus. Coll., Reg. No. D. 13,340.

Shell of medium size, very slightly curved and very gradually tapering, circular, polished, white; accremental striae fine and regular; aperture round, peristome thin; apex large with a narrow tube projecting from the centre of the disc, closing the posterior end; this appendix is visible in very early life, when the shell is extremely narrow. In the still earlier stages of growth, when the appendix is absent, the shell resembles *D. jaffaensis,* but has straighter sides, as it does not widen so rapidly; the present specimens have more marked concentric striations.

Dimensions—Shell: Length, 19 mm.; breadth, 2 mm. Appendix: Length, 1 mm.; breadth, ·3 mm.

Recent, Flindersian, deep water.

Type Locality—Cape Borda, S.A., 60 fathoms.

Observations—This shell is much larger, thicker and straighter than the Peronian *D. virgula.*

DENTALIUM HYPERHEMILEURON Verco, 1911

D. hyperhemileuron Verco, 1911 Trans. Roy. Soc. S. Aust., **35**, 217, pl. xxvi, figs. 3, 3A; Cotton and Godfrey, 1933 *loc cit.*, 146, pl. i, figs. 3, 3A

Type Locality—King George Sound, W.A.

Recent, Flindersian, shallow water.

Subgenus FISSIDENTALIUM Cossmann, 1888
(Genotype *Dentalium ergasticum* Fischer)

Dentalium verconis sp. nov.
Pl. xii, fig. 1

D. zelandicum Cotton and Godfrey, 1933 *loc. cit.*, 145, non Sowerby

Holotype—S.A. Mus. Coll., Reg. No. D. 13,341.

Shell large, white, very solid, slightly curved towards the posterior end; aperture irregular, dorsally produced; peristome thin and sharp, displaying the numerous longitudinal ribs; apex fairly large, orifice small, walls thick; a simple, short, ventral fissure about 2 mm. in length; sculpture of numerous (about twenty) primary, narrow, rounded ribs at the anterior end, of subequal strength, with only two or three in all minor intercalations; interspaces wider, both ribs and interspaces crossed by regular, fine, oblique, growth-striae.

Dimensions—Length, 47 mm.; breadth, 6 mm.

Type Locality—Beachport, S.A., 200 fathoms.

Recent, Flindersian, deep water.

Observations—This species has been recorded as *D. zelandicum* Sowerby (type locality, New Zealand) from South Australia, but differs in having only half as many primary ribs which are subequal, not unequal; the maximum size of the species is less than the average adult *zelandicum.*

Dentalium jaffaensis sp. nov.
Pl. xii, fig. 5

D. lubricatum Cotton and Godfrey, 1933 *loc. cit.*, 145, pl. i, figs. 4, 4A, non Sowerby

Holotype—S.A. Mus. Coll., Reg. No. D. 13,337.

Shell of medium size, smooth, polished, white, gradually increasing in diameter, slightly curved; aperture regular, peristome thin, easily broken; apex small, with no slit in the early stage of growth but a central posterior aperture; protoconch an elliptical bulb with a very short, slightly contracting, round, tubular posterior prolongation set somewhat obliquely to the axis of the bulb and directed towards the convex side of the shell; opaque transverse rings appear in the first 1·5 mm. of the shell, and the adult has a slit at the posterior end on the convex or ventral side.

Dimensions—Length, 24 mm.; breadth, 2·7 mm.

Type Locality—Cape Jaffa, S.A., 90 fathoms.

Recent, Flindersian, deep water.

Observations—Related to the Peronian *D. lubricatum* Sowerby and *D. virgula* Hedley, but more slender, straighter, and less rapidly expanding than *D. lubricatum*.

III FOSSIL SPECIES

For the most part, fossil species have provided little difficulty. Almost all were described by Tate in 1887 and 1899, lists of localities being published in each case. Further localities have been recorded by Chapman in his work on the Mallee and other Victorian bores, including (with Miss I. Crespin and R. A. Keble) the Sorrento Bore, and by Howchin in papers upon bores in the Adelaide basin. Additional localities are here listed, specimens from which, unless otherwise stated, are in the Commonwealth Palaeontological Collection at Canberra.

Class SCAPHOPODA

Family DENTALIIDAE

Genus Dentalium Linne, 1758

Subgenus Fissidentalium Fischer, 1885
(Genotype *D. ergasticum* Fischer, 1882)

Dentalium bifrons Tate

Dentalium (?) *bifrons* Tate, 1887 Trans. Roy. Soc. S. Aust., **9**, 192, pl. xx, fig. 5; Harris, 1897 Cat. Tert. Moll. Brit. Mus., 295; Tate, 1899 Trans. Roy. Soc. S. Aust., **33**, 261

Type Locality—Lower Pliocene, Muddy Creek, Victoria.

Locality not previously recorded—Abattoirs Bore, S.A., Lower Pliocene (Howchin, Upper Pliocene), in Tate Mus. Coll. Adel. Univ.

Dentalium mantelli Zittel

Dentalium sp. nov. Mantell, 1850 Quart. Journ. Geol. Soc., **6**, 331, pl. xxviii, fig 15

Dentalium mantelli Zittel, 1864 Novara-Exped., Neu-Seeland. Abth. Palae., 45, pl. xiii, figs. 7A, 7B

Entalis mantelli Zittel: Tate, 1887 Trans. Roy. Soc. S. Aust., **9**, 190

Dentalium mantelli Zittel: Pilsbry and Sharp, 1897 Man. Conch., **17**, 208; Harris, 1897 Cat. Tert. Moll. Brit. Mus., (i), 293; Tate, 1899 Trans. Roy. Soc. S. Aust., **23**, 261

D. (Entalis) mantelli Zittel: Howchin, 1935 *id.*, **59**, 74, 75

Type Locality—Oligocene, The Cliffs, Nelson, New Zealand.

The very lengthy synonymy of *D. mantelli* is here reduced to references concerning Australia only; those relating to the occurrence of the species in New Zealand are listed by Suter, N.Z. Geol. Surv. Pal., Bull. No. 2, (i), 32.

This is a very variable species, common in both Australia and New Zealand. It presents difficulty in that the early references do not properly designate the type. Both Zittel and Suter place The Cliffs near Nelson first in the list of localities, thus apparently excluding Mantell's Onekakara shell. It seems that one must accept Zittel's figured specimen from The Cliffs as the holotype, which Suter states is in the K.K. Höfmuseum, Vienna.

The type locality, moreover is a poor collecting ground, so that it is difficult to obtain specimens of true *mantelli*. Tate (1877) states that a comparison of authentic specimens was made by him; Suter's figures of plesiotypes agree with Australian specimens, in view of which we here retain the identity of the Australian with the New Zealand species.

Localities not previously recorded:

Outcrops—Bird Rock, Torquay, Vic., Lower Miocene; 3 miles west of Gellibrand R., Vic., L. Miocene; Clifton Bank, Muddy Ck., Vic., L. Miocene; Skinner's, Bairnsdale area, Vic., L. Miocene; "Goodwood," Hawkesdale, Vic., L. Pliocene (Kalimnan).

Borings—P. of Colquhoun No. 1, Lakes Entrance Devel. Co., L. Bunga, Vic., 903 ft., Upper Oligocene; P. of Nindoo, Gippsland, Vic., 208 ft., L. Miocene; P. of Meerlieu, Gippsland, Vic., 570 ft., L. Miocene; New Shaft, Altona, Vic., 226 ft., L. Miocene; Hamilton Bore, Vic., 20-25 ft., L. Miocene; Oil Search Steam Drill, P. of Coolgulmerung, Gippsland, Vic., 300-334 ft., L. Pliocene (Kalimnan).

Subgenus Paradentalium Cotton and Godfrey, 1933
(Genotype *D. bednalli* Pilsbry and Sharp)

Dentalium aratum Tate

Dentalium aratum Tate, 1887 Trans. Roy. Soc. S. Aust., **9**, 192, pl. xx, fig. 8; Tate, 1899 idem, **23**, 265

Type Locality—Lower Miocene, River Murray Cliffs.

Localities not previously recorded:

Outcrops—3 miles west of Gellibrand R., Vic., L. Miocene; Clifton Bank, Muddy Creek, Vic., L. Miocene.

Borings—No. 1, P. of Bumberrah (Metung), Vic., 180-190 ft., L. Pliocene (Kalimnan); No. 1, P. of Bengworden, Gippsland, Vic., 470 ft., L. Pliocene (Kalimnan).

DENTALIUM LATESULCATUM Tate

D. latesulcatum Tate, 1899 Trans. Roy. Soc. S. Aust., **23,** 262, pl. viii, fig. 9

Type Locality—Lower Pliocene, Grange Burn, near Hamilton, Vic.

Locality not previously recorded:

Boring—No. 3, Lakes Entrance, Vic., 90 ft., L. Pliocene (Kalimnan).

DENTALIUM SEMIARATUM Chapman and Crespin

Dentalium semiaratum Chapman and Crespin, 1928 Rec. Geol. Surv. Vic., **5,** (i), 105, pl. vi, fig. 28

Type Locality—Lower Pliocene, Sorrento Bore, 719 ft.

Localities not previously recorded:

Borings—P. of Meerlieu, Gippsland, Vic., 260 ft., Middle Miocene; No. 14, P. of Stradbroke, Gippsland, Vic., 245 ft., Lower Pliocene; No. 15, P. of Stradbroke, Gippsland, Vic., 440 ft., Upper Oligocene.

Dentalium howchini sp. nov.

Pl. xii, fig. 6

D. elephantinum Tate, 1890 Trans. Roy. Soc. S. Aust., **13,** (ii), 177, non Linne

D. octogonum Tate, 1890 *id.*, non Lamarck

D. sectum, Tate, 1890 *id.*, non Deshayes

D. intercalatum Howchin, 1936 Trans. Roy. Soc. S. Aust., **60,** 16, non Gould

D. intercalatum aratum Howchin, 1936 *id.*, non Tate

D. intercalatum franciscense Howchin, 1936 *id.*, non Verco

D. intercalatum var. Howchin, 1936 *id.*, 17

D. sp. Howchin, 1936 *idem*

Holotype—Tate Mus. Coll., Adel. Univ.

Shell large, white, boldly sculptured with intercalating ribs numbering in the holotype 13; interstices average about the width of the ribs or a little narrower; the ribs split towards the anterior end by gradually deepening sulci; accremental striae irregular and rather coarse in places; aperture rounded, peristome regular, fairly thick, undulated on the exterior by the section of the ribs; posterior opening small.

Dimensions—Length, 45 mm.; breadth, 7 mm.

Type Locality—Abattoirs Bore, S.A., Lower Pliocene (Howchin "Adelaidean," Upper Pliocene).

Paratypes—In various specimens, the number of primary ribs varies from 7 to 16; splitting of the ribs towards the anterior by gradually deepening sulci frequently doubles the number of ribs.

Observations—This is a very variable species, related to *D. mantelli,* from which it differs in being much more boldly sculptured and in having a dominant intercalating system of ribs. It is somewhat like the common New Guinea fossil species *D. subrectum* Mart., which has narrower ribs.

Subgenus GRAPTACME Pilsbry and Sharp, 1897
(Genotype *D. semistriatum* Turton)

DENTALIUM SECTIFORME Tate

D. sectiforme Tate, 1899 Trans. Roy. Soc. S. Aust., **23**, 262, pl. viii, figs. 6, 6A

Type Locality—Lower Pliocene, Muddy Creek, Vic.

Subgenus LAEVIDENTALIUM Cossmann, 1888
(Genotype *D. incertum* Deshayes)

DENTALIUM SUBFISSURA (Tate)

Entalis subfissura Tate, 1887 Trans. Roy. Soc. S. Aust., **9**, 191, pl. xx, figs. 4A, 4B

Dentalium subfissura Tate: Harris, 1897 Sat. Tert. Moll. Brit. Mus., 296; Tate, 1899 Trans. Roy. Soc. S. Aust., **23**, 263

Type Locality—Lower Miocene R. Murray Cliffs, S. Aust.

Localities not previously recorded:

Outcrop—Clifton Bank, Muddy Creek, Vic., Lower Miocene.

Borings—New Shaft, Altona, Vic., 226 ft., Lower Miocene; No. 8, P. of Glencoe, Gippsland, Vic., 570 ft., Lower Pliocene (Kalimnan); No. 1, P. of Bumberrah, Gippsland, Vic., 239 ft., Lower Pliocene (Kalimnan).

DENTALIUM PICTILE Tate

Entalis subfissura Tate: Tate and Dennant, 1896 Trans. Roy. Soc. S. Aust., **20**, (i), 134

Dentalium pictile Tate, 1899 *id.*, **23**, 263, pl. viii, fig. 8

Type Locality—Lower Miocene, Table Cape, Tas.

Locality not previously recorded:

Boring—New Shaft, Altona, Vic., Lower Miocene.

DENTALIUM LARGICRESCENS Tate

D. largicrescens Tate, 1899 Trans. Roy. Soc. S. Aust., **23**, 264, pl. viii, figs. 10, 10A

Type Locality—Lower Miocene, Beaumaris, Vic.

Localities not previously recorded:

Outcrops—Skinner's, Bairnsdale area, Vic., Lower Miocene; 3 miles west of Gellibrand R., Vic., Lower Miocene; Rose Hill, Vic., (?) Upper Miocene; Old Bunga, east of No. and Bore, L. Entrance, Vic., Lower Pliocene (Kalimnan).

Borings—No. 1, Kalimna Oil Co., Rigby Is., L. Entrance, Vic., 30-50 ft., Lower Pliocene (Kalimnan); No. 1, Kalimna Oil Co., Rigby Is.,

L. Entrance, Vic., 70 ft., Lower Pliocene (Kal.); Signal Hill, P. of Dulungalong, Vic., 300-650 ft., Lower Pliocene (Kal.); P. of Wulla Wullock, Vic., 432 ft. Lower Pliocene (Kal.); Darriman, No. 3, Vic., 66-76 ft. Lower Pliocene (Kal.); P. of Glencoe, No. 7, Vic., 170 ft., Lower Pliocene (Kal.); No. 1, P. of Bumberrah (Metung), Vic., 160-170 ft., Lower Pliocene (Kal.); No. 1, P. of Bumberrah (Metung), Vic., 170-180 ft., Lower Pliocene (Kal.); No. 1, P. of Bumberrah (Metung), Vic., 190-200 ft., Lower Pliocene (Kal.).

Dentalium lacteolum Tate

Dentalium lacteum Tate, 1887 Trans. Roy. Soc. S. Aust., **9,** 193, non Deshayes

D. lacteolum Tate, 1899 *id.,* **23,** 264

Type Locality—Lower Miocene, Muddy Creek, Vic.

Localities not previously recorded:

Outcrop—3 miles west of Gellibrand R., Vic., Lower Miocene.

Borings—Hamilton Bore, 25-30 ft., Lower Miocene; Hamilton Bore, 114-119 ft., Lower Miocene.

Subgenus Fustiaria Stoliczka, 1868
(Genotype *D. circinatum* Sowerby)

Dentalium acriculum (Tate)

Entalis acriculum Tate, 1887 Trans. Roy. Soc., S. Aust., **9,** 192, pl. xx, fig. 11

Dentalium acriculum Tate: Harris, 1897 Cat. Tert. Moll. Brit. Mus., 296; Tate, 1899 Trans. Roy. Soc. S. Aust., **23,** 264

Type Locality—Lower Miocene, Muddy Creek, Vic.

Dentalium australe Pilsbry and Sharp

Entalis annulatum Tate, 1887 Trans. Roy. Soc. S. Aust., **9,** 191, pl. xx, fig. 6A-6B

Dentalium australe Pilsbry and Sharp, 1898 Tryon's Man. Conch., **17,** 192, nom. mut. for *D. annulatum* Tate (preocc.); Tate, 1899 Trans. Roy. Soc. S. Aust., **23,** 264

Type Locality—Lower Miocene, Muddy Creek, Vic.

Locality not previously recorded: Bird Rock, Torquay, Vic., Lower Miocene.

Subgenus Episiphon Pilsbry and Sharp, 1898
(Genotype *D. sowerbyi* Guilding)

Dentalium tornatissimum Tate

D. tornatissimum Tate, 1899 Trans. Roy. Soc. S. Aust., **23,** 265, pl. viii, fige. 7-7A

Type Locality—Lower Pliocene (Kalimnan), Gippsland Lakes, Vic.

Localities not previously recorded:

Borings—No. 1, P. of Bumberrah (Metung), Vic., 90-100 ft., Lower Pliocene (Kal.); No. 1, P. of Bumberrah (Metung), Vic., 110-130 ft., Lower Pliocene (Kal.); No. 1, Kalimna Oil Co., Rigby Is., Lakes Entrance, 30 ft., Lower Pliocene (Kal.); No. 1, Kalimna Oil Co., Rigby Island, Lakes Entrance, 50 ft., Lower Pliocene (Kal.).

Subgenus GADILINA Foresti, 1895
(Genotype *D. triquetrum* Brocchi)

DENTALIUM TATEI Pilsbry and Sharp

Dentalium (?) *triquetrum* Tate, 1887 Trans. Roy. Soc. S. Aust., **9,** 193, pl. xx, fig. 3, non Brocchi

D. tatei Pilsbry and Sharp, 1898 Tryon's Man. Conch., **17,** 218, nom. mut.; Tate, 1899 Trans. Roy. Soc. S. Aust., **23,** 266

Type Locality—Lower Miocene, Adelaide Bore, S. Aust.

IV ACKNOWLEDGMENTS

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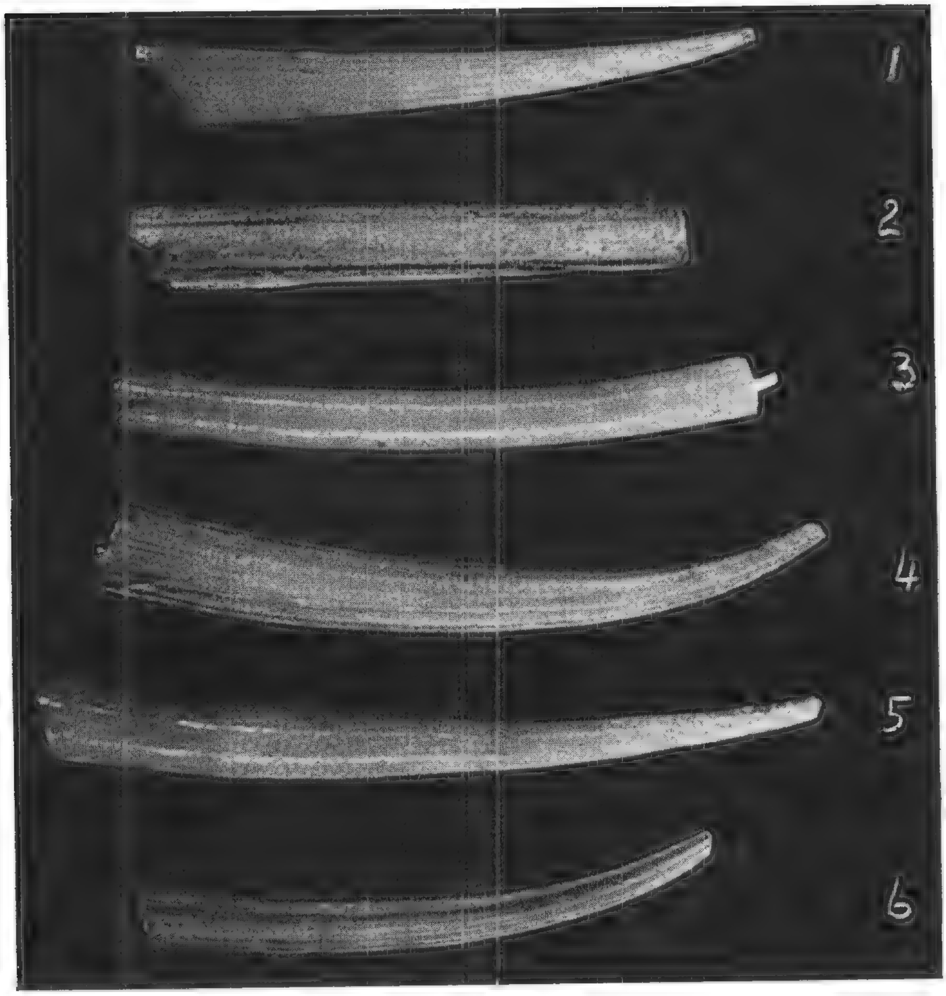
VI EXPLANATION OF PLATE XII

Fig. 1 *Dentalium (Fissidentalium) verconis*, sp. nov. x 1·6
Fig. 2 *Dentalium (Eudentalium) beachportensis*, sp. nov. x 4
Fig. 3 *Dentalium (Episiphon) bordaensis*, sp. nov. x 4
Fig. 4 *Dentalium (Paradentalium) flindersi*, sp. nov. x 4·5
Fig. 5 *Dentalium (Fissidentalium) jaffaensis*, sp. nov. x 3·6
Fig. 6 *Dentalium (Paradentalium) howchini*, sp. nov. x 1·5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THE CLIMATE OF TROPICAL AUSTRALIA IN RELATION TO POSSIBLE AGRICULTURAL OCCUPATION

BY J. A. PRESCOTT.

Summary

INTRODUCTION

The stndy of agro-climatology has received considerable impetus during recent years owing to the concept of climatic factors which simultaneously take into account rainfall, temperature and relative humidity and which can be related to soil moisture. Reference may be made to the recent summary of the principles involved (Prescott, 1938) and, as regards the practical application of the method to an agricultural problem in South Australia, to the work of Trumble (1937).

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[Read 14 July 1938]

Introduction

The study of agro-climatology has received considerable impetus during recent years owing to the concept of climatic factors which simultaneously take into account rainfall, temperature and relative humidity and which can be related to soil moisture. Reference may be made to the recent summary of the principles involved (Prescott, 1938) and, as regards the practical application of the method to an agricultural problem in South Australia, to the work of Trumble (1937).

The purpose of the present contribution is to analyse the factors, principally those relating to moisture conditions, that are likely to determine the trend of agricultural and pastoral occupation in those parts of Australia which lie north of the Tropic of Capricorn, with particular emphasis on the areas receiving seasonal rainfall typically monsoonal in character. For purposes of comparison, a similar analysis has been made of the climate of Nigeria, using the data of Brooks (1916, 1920), which data have been amplified by personal access to the records of the London Meteorological Office, through the courtesy of Dr. Brooks himself

The parallel between tropical Australia and West Africa is only complete for the strictly monsoonal areas; the east coast of Australia is a trade wind coast, whereas the wetter parts of West Africa have an equatorial climate. A comparison with the French territories of Senegal, Upper Niger and Upper Volta would possibly be more instructive as lying in latitudes more similar to those of tropical Australia, but the data for these territories are not so complete nor so readily accessible as those for British Nigeria.

In the analysis of the data, use has been made of the ratio of the mean monthly rainfall to saturation deficit, the first expressed in inches of rain and the second in inches of mercury. No data for evaporation are available for the Australian area under consideration except for Boulia, which is on the desert margin. An evaporimeter tank has only recently been installed alongside the aerodrome in Darwin.

Monthly Ratios of Rainfall to Saturation Deficit

Two critical values for the ratio of rainfall to saturation deficiency have been adopted. The first, a monthly ratio of 5, is based on the previous work of Prescott (1936, 1938) and Trumble (1937) and represents the limiting ratio required to keep the surface soil above the wilting point of plants. Where this value is not reached for any of the twelve months of the year, desert conditions may be expected to prevail; the length of the agricultural or pastoral season can be regarded as the period during which this value is exceeded.

The second monthly ratio is that of 35, which is based on the evaporation from a saturated soil or from an actively growing dense crop under ideal conditions. Under either of these conditions the evaporation from the soil or crop tends to a value of about 1·6 to 1·7 times that from a free water surface, and it is obvious that more rain will be required than that just sufficient to balance the evaporation from a water surface if the native vegetation or the crops grown are to be vigorous.

These ratios of the rainfall to saturation deficiency have therefore been calculated for the tropical stations of Australia from the data published in Pamphlet No. 42 of the Council for Scientific and Industrial Research and the isologs of the ratio mapped from the values so obtained and by interpolation on maps on which were successively superposed altitude, temperature, humidity, saturation deficit and rainfall. The maps showing the values of this ratio for the twelve months of the year are shown in figs. 8a, 8b, and 8c, in which the march of the monsoon into tropical Australia can be readily observed. The possibility of agricultural or pastoral occupation will be determined, so far as climate is concerned, by these monthly trends.

This series of maps reveals that the greater part of tropical Australia is subject to seasonal drought for eight months of the year, and that the very wet conditions corresponding to a ratio of P/s.d. of 35 prevail only for three months of the year along the northern coast line, and with small areas along the east coast with up to eight months as at Innisfail in North Queensland.

During the driest months a narrow belt which is practically completely rainless moves westward, starting in August from the south-west coast of the Gulf of Carpentaria, moving along the coast of the Kimberleys, finishing in October, and continuing in November at Onslow in Western Australia. A further feature indicated in fig. 1A is the small area, including Townsville, Charters Towers and Ayr, which has the benefit of the "lesser rains" for a brief period in mid-winter, the prevailing low temperatures enabling a relatively low amount of rain to be efficient in maintaining soil moisture. This period cannot be regarded, however, as a reliable feature of the local climate.

Length of Season

The essential facts with respect to the length of the season are indicated in the maps of fig. 1, where the number of months during which soil moisture conditions may be considered to be satisfactory (P/s.d. being greater than 5), and where conditions of real wetness prevail (P/s.d. being greater than 35) are indicated as isochrones. This pair of maps may be compared with the tropical part of the bioclimatic map of Davidson (1936), the principles employed in their construction being essentially similar to those employed by Davidson.

These maps reveal that the characteristic feature of the climate over most of the area is its extreme seasonal character, the length of the seasonal drought being as important as the length of the wet season and determining to a considerable extent the character of the native vegetation. The geographical limits of the grasslands and open savannahs on heavy soils correspond approximately to the seasonal isochrones of three and four months. With a season of from four to six months in length, savannah woodlands prevail. Where the middle months of the rainy season are very wet, local swamps become important in low country and sclerophyll forests are encountered on the higher ground. The true rain forests of the Queensland coast are associated with short seasonal droughts and with several months of very wet conditions. Many so-called rain forests in the monsoonal belt are essentially "corridor" forests along the banks of permanent rivers, and the trees and palms growing in them are usually capable of with-

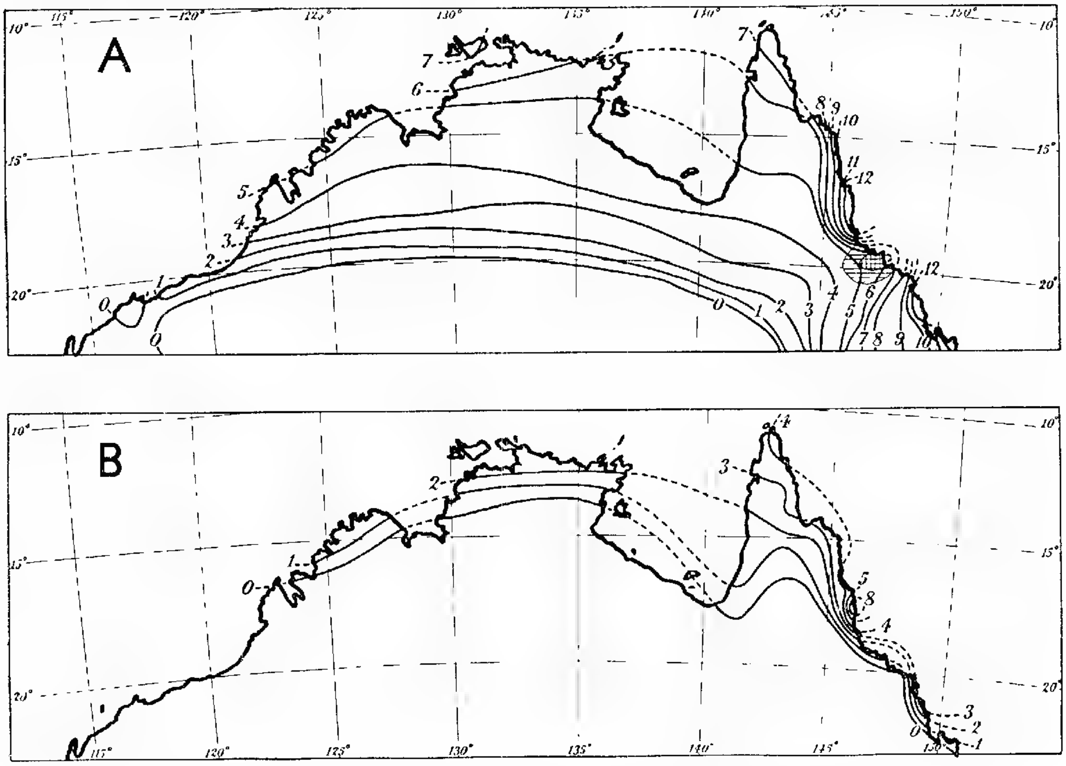

Fig. 1 Maps of tropical Australia showing isochrones of the length of the season:
A. Length of the wet season in months (the ratio of precipitation to saturation deficiency is greater than 5).
B. Length of the very wet season in months (the ratio of precipitation to saturation deficiency is greater than 35). The isochrone for three months in all probability crosses Melville Island.

standing a considerable degree of atmospheric dryness. The trees of the savannah woodlands and savannahs are also adapted to the dry conditions of the winter and many of them, typified by the *Bauhinia,* lose their leaves at the end of the dry season.

An excellent comparison and contrast for two localities having semi-humid climates with seasonal rainfall is afforded by that between Adelaide and Darwin. Both are near the coast of a large gulf protected by a large island. The rainfall in Adelaide falls in winter, that in Darwin in summer, the length of the wet season being in each case 6·6 months. It is the drought period which is of some significance—the mean saturation deficit for the winter six months at Darwin is 0·40 inches, and in Adelaide for the summer six months it is 0·42 inches, so that evaporation in the dry season is probably the same in both places. The mean temperature for the winter six months in Darwin is, however, 81° F., while in Adelaide for the summer six months it is only 70° F. Adelaide is in the heart of a thriving agricultural community based on the cultivation of Mediterranean annual crops and drought resisting perennial trees and pastures. Any possible agriculture in the vicinity of Darwin must similarly be based on specialized crops suited to monsoonal conditions.

Agriculture and Seasonal Rainfall

Before proceeding to a further discussion of possible agricultural developments in tropical Australia, it would be well to define the climatic requirements of an agricultural system based on the acceptance of a period of seasonal drought.

Experience at the Waite Institute, near Adelaide, may be taken as affording some evidence. The crops successfully grown are wheat, barley and oats, the principal grasses and all the clovers are Mediterranean annuals. Perennial grasses and forage plants are limited to *Phalaris,* perennial rye grass selected for drought resistance, the native grasses such as *Danthonia* and *Themeda,* and lucerne. The climate is too cold in winter and too dry in summer for cocksfoot or for red and white clover. Both peas as a crop and subterranean clover as a pasture plant need to be selected for earliness, so as to set seed before the beginning of the summer drought. Being shallow rooted they are not able to rely on reserves of subsoil moisture. The monthly trends of the ratio of rainfall to saturation deficiency at this centre are indicated in fig. 2, in which the relationship of these ratios to the agricultural season for different crops is also shown diagrammatically.

In the same diagram is set out information regarding two centres in Nigeria, Kano and Ilorin, for both of which cropping records are available in the Bulletins of the Nigerian Agricultural Department (1930, 1931). Kano is typical of the true monsoonal belt and, as will be noted later, the seasonal rainfall is equal in amount to that of Katherine in the Northern Territory. The crops that are possible are strictly limited to those suitable for short seasons. Kano is the most important Nigerian centre for the cultivation and export of the peanut. Ilorin is transitional in climate between the monsoonal and equatorial regions. Both early and late sown maize are possible at this centre, although the latter is rare, yams become important as a crop. The most important tropical grain crop is guinea corn *(Sorghum vulgare).* Where the seasons are shorter and the rainfall less, guinea corn is replaced by bulrush millet *(Pennisetum typhoides).* It is to be noted that farming is practised to the northern boundary of Nigeria and for some distance beyond, into French territory. In the far north-east, Geidam, with a rainfall of 14·3 inches and a season 2·4 months in duration, is on the extreme boundary of agricultural occupation.

A great assortment of crops has been listed for the West African territories, and an equally great variety for any one crop. Reference in this connection may

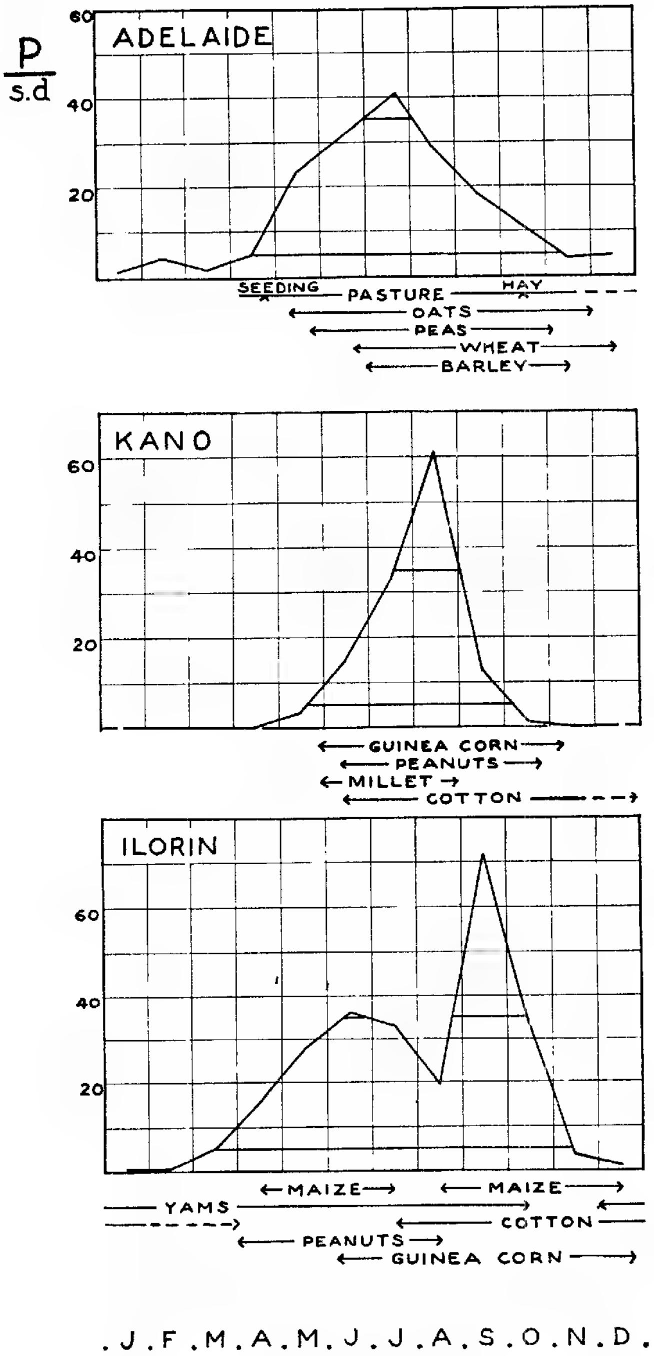

Fig. 2

Climatic characteristics with respect to the monthly ratio of rainfall to saturation deficit for agricultural localities with marked seasonal rainfall. Adelaide is selected as representative of the Mediterranean climate. Kano is representative of a long established centre with a short monsoonal climate, and Ilorin as a centre transitional in climate between the monsoonal and equatorial types. The monthly ratios of 5 and 35 are indicated by heavy horizontal lines, the length of which corresponds to the wet season and very wet season, respectively.

be made to Meniaud (1912), Sampson (1936), Dalziel (1937), and to the Nigerian Year Books. From the crop maps of the latter the following list of principal crops and natural plant products has been drawn up, together with a rough estimate of the climatic requirements of each.

Crop or Product	Annual Rainfall Inches	Length of Season Months
Millets *(Pennisetum typhoides)* - -	20–40	3·4–5·4
Ground nuts *(Arachis hypogaea)* - -	34	4·7
Cotton *(Gossypium spp.)* - - -	40–48	5·5 7·0
Ginger *(Zingiber officinalis)* - - -	45	5·8
Shea nuts *(Butyrospermum parkii)* -	48	6·5
Cassava *(Manihot utilissima)* - -	20 91	3·0–11·3
Guinea corn *(Sorghum vulgare)* - -	40–47	5·9–6·7
Yams *(Dioscorea spp.)* - - - -	40–110	7·2 12·0
Maize *(Zea mays)* - - - -	42–72	8·0–11·0
Beniseed *(Sesamum orientale)* - -	50	7·8
Palm kernels *(Elaeis guineensis)* -	90–140	11·0–12·0
Cocoyam *(Colocasia antiquorum)* -	70	9·0

As the whole of Nigeria with the exception of the region of Lake Chad is potentially agricultural, a detailed comparison between the climates of selected stations in tropical Australia and in Nigeria may next be attempted. The isochrones of the length of the agricultural season in Nigeria are shown in the map of fig. 7, which is also a guide to the localities discussed in the text. The comparison between the pairs of stations has been done diagrammatically in figs. 4 and 5. Three aspects are to be compared; these are: (1) seasonal rainfall, (2) length of season, (3) temperature. The differences in latitude and the proximity to the Sahara make the Nigerian stations hotter than Australian stations in the dry season, but in the wet season the temperatures more nearly compare with those of Australia. Another feature which the diagrams bring out is that the dry season is virtually rainless in Northern Nigeria. Each of the pair of stations has approximately the same rainfall. The agricultural season has been defined as the period during which the monthly ratios of rainfall to saturation deficiency exceed the value of 5, and the very wet season the period during which the value of 35 is exceeded.

For cultivated crops adapted to seasonal rainfall and capable of high yields, the agricultural season should probably exceed six months, one month of which should be very wet in terms of the above ratios. Where the agricultural season is shorter, crops especially adapted to these conditions are required, the most important of which will be millets and peanuts.

The data relating to the above-mentioned pairs of stations are summarised numerically in Table I.

TABLE I

Comparison of Stations in Australia and Nigeria with respect to Rainfall and the Length of the Agricultural Season.

AUSTRALIAN STATIONS

	Annual Rainfall, Inches	Length of Agricultural Season, Months	Length of Very Wet Season, Months
Tennant's Creek	14·7	1·2	0·0
Hall's Creek	20·8	3·0	0·0
Daly Waters .. .	26·5	4·1	0·0
Normanton	38·7	4·7	0·4
Herberton	43·0	9·5	3·1
Atherton	51·8	9·9	3·6
Cairns	88·4	12·0	4·2
Innisfail	142·6	12·0	8·8

NIGERIAN STATIONS

	Annual Rainfall, Inches	Length of Agricultural Season, Months	Length of Very Wet Season, Months
Geidam	14·3	2·4	0·0
Maiduguri	22·2	3·6	0·2
Sokoto	25·2	4·1	0·0
Yola	38·7	6·3	1·1
Zaria	44·8	5·8	2·3
Ilorin	49·3	7·9	2·0
Benin	90·8	11·3	7·2
Forcados	142·2	12·0	7·6

Generally speaking, from the diagrams and from the tables, it will be seen that for equal rainfalls in the more arid regions the moisture conditions with regard to both the length of the season and the efficiency of the rainfall are in favour of Nigeria. The temperatures at Atherton and Herberton do not compare with the corresponding stations, Zaria and Ilorin, owing to the position of the Australian stations on the Atherton tableland.

RELIABILITY OF SEASONAL RAINFALL

A very important factor making for the permanent agricultural occupation of Nigeria is the reliability of the rainfall, and a comparison between West African stations and Australian stations is instructive in this respect. For this purpose the rainfall records at a number of selected stations have been examined and the rainfall for each season determined, winter rains being excluded. In the case of Katherine the monthly rains were excluded at the beginning and end of the season, which were below the values required to give a value of 5 to the ratio of rainfall to the assumed average saturation deficit for the particular month.

The data for a group of stations are given below, the variability of the seasonal rainfall is expressed as the standard deviation.

Mean Seasonal Rainfall and Standard Deviation (Inches)

AUSTRALIAN STATIONS

Darwin - - -	59·6 ± 10·3
Normanton - -	37·0 ± 13·9
Katherine - -	34·5 ± 10·4
Georgetown - -	32·1 ± 10·8
Donor's Hill -	26·1 ± 12·0
Wyndham - -	25·6 ± 8·6
Daly Waters - -	24·9 ± 8·7
Hall's Creek - -	19·4 ± 7·2

WEST AFRICAN STATIONS

Bathurst (Gambia)	46·7 ± 12·4
Kano - - - -	34·4 ± 5·5
Sokoto - - -	29·0 ± 4·0
Maiduguri - -	25·8 ± 6·3
Hadeija - - -	20·9 ± 3·9

The variability at Bathurst is seen to be of the same order as in Australia, for the Nigerian stations the variability is only half that of the Australian stations.

An instructive comparison is available in the two stations Katherine and Kano. The seasonal rainfall in each case is 34·5 inches, and both are centres for the cultivation of the peanut. The standard deviation at Katherine over the 65 seasons from 1872 to 1937 is ± 10·44 inches, the effective length of the season has varied from 3 months to 6 months, with a mean of 4·45 months, while the lowest seasonal rainfall has been 16·7 inches and the highest 70·7 inches.

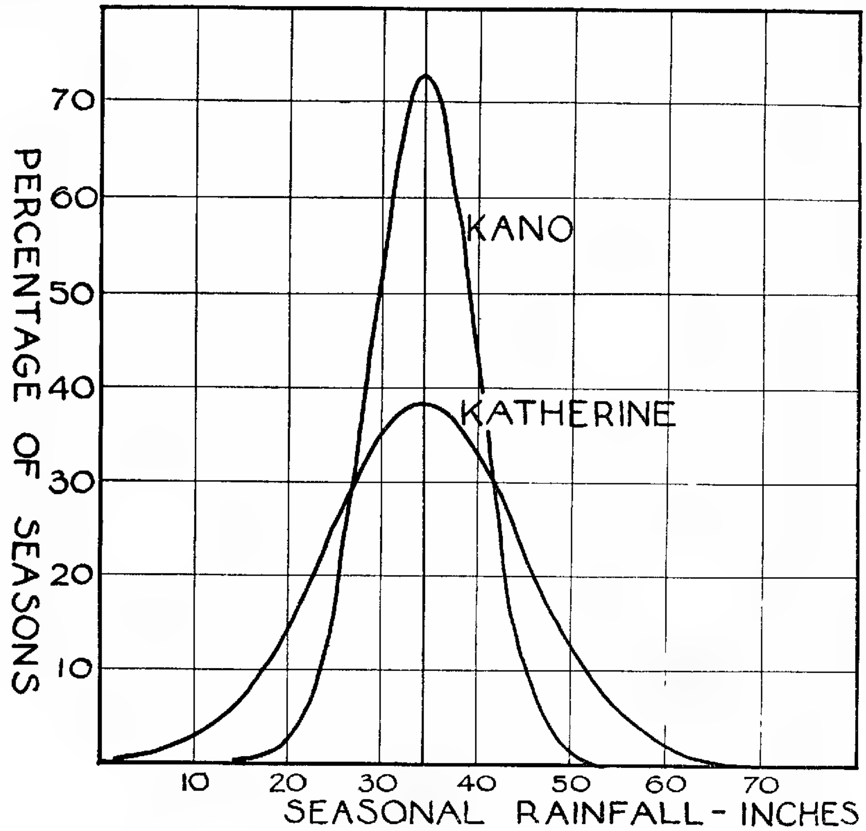

Fig. 3

Frequency distribution curves of the seasonal rainfall at Kano and Katherine. Both stations have the same seasonal rainfall, but the proportion of years likely to receive within 5 inches of the mean is over 70 per cent. for Kano and less than 40 per cent. for Katherine. The differences in the range between the lowest and the highest likely seasonal rainfall should also be noted.

At Kano, over a period of 17 years, the standard deviation of the seasonal rainfall has been ± 5·48 inches, and the range has been from 26·6 inches to 45·7 inches.

The distributions are sufficiently close to normal to justify a comparison of the theoretical frequency distribution curves (fig. 3). The essential facts regarding the comparison are well summarised in these curves. Reliability of rainfall

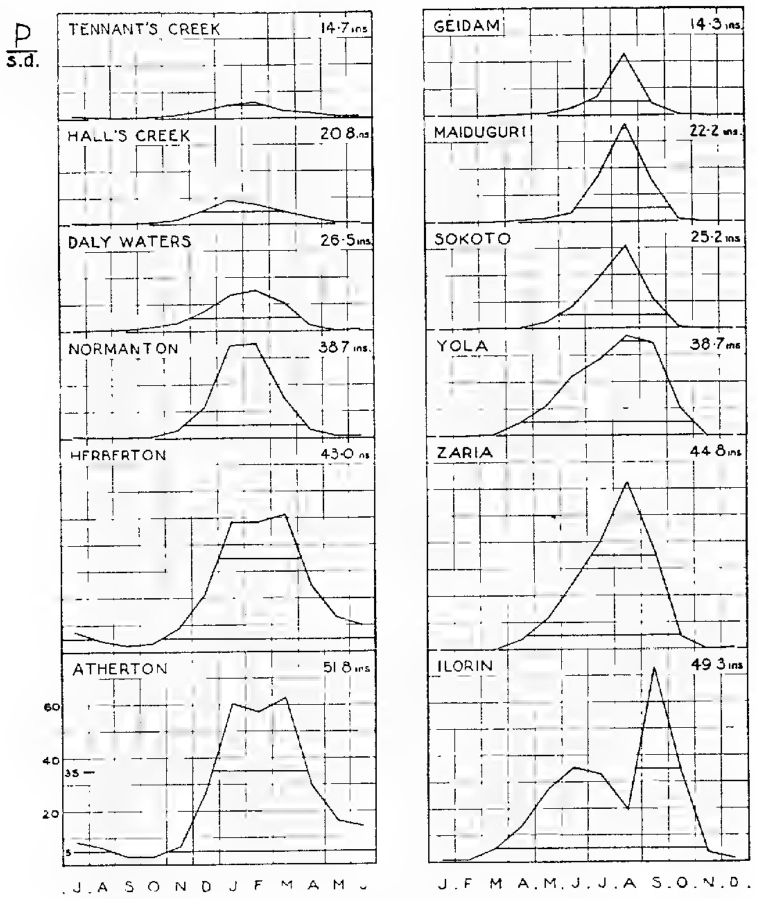

Fig. 4a

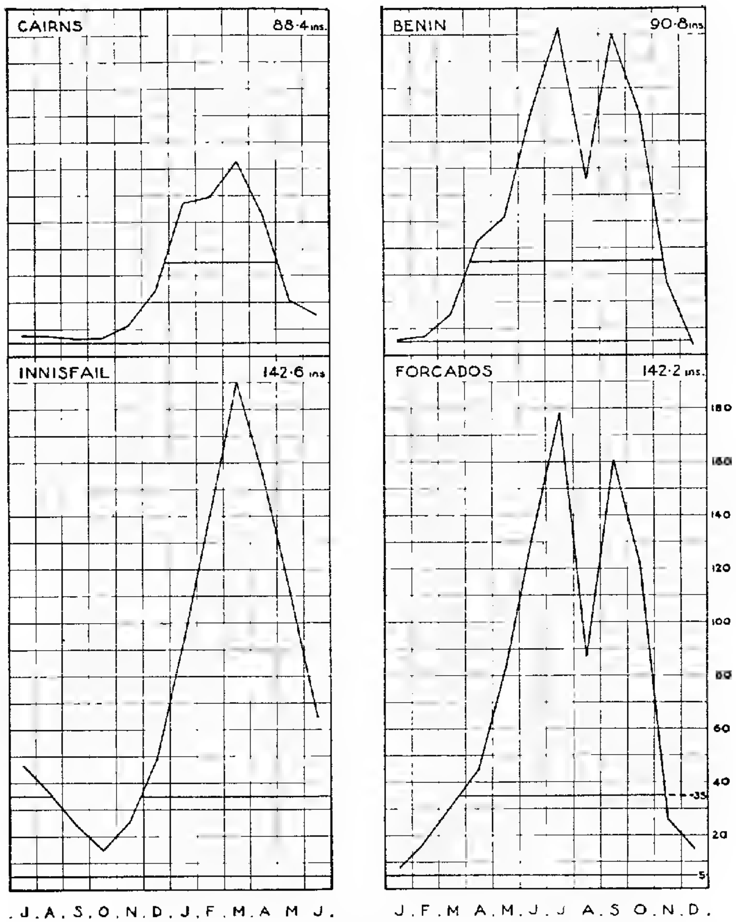

Fig. 4b

Comparison with respect to the ratio of precipitation to saturation deficit of pairs of stations from Australia and Nigeria having similar rainfalls. The monthly ratios of 5 and 35 are indicated by heavy horizontal lines, the length of which corresponds to the wet season and very wet season, respectively.

is an important factor in the permanence of any agricultural system; the relatively low reliability of the Australian monsoon is a factor that should be considered in any discussion of possible agricultural systems for tropical Australia.

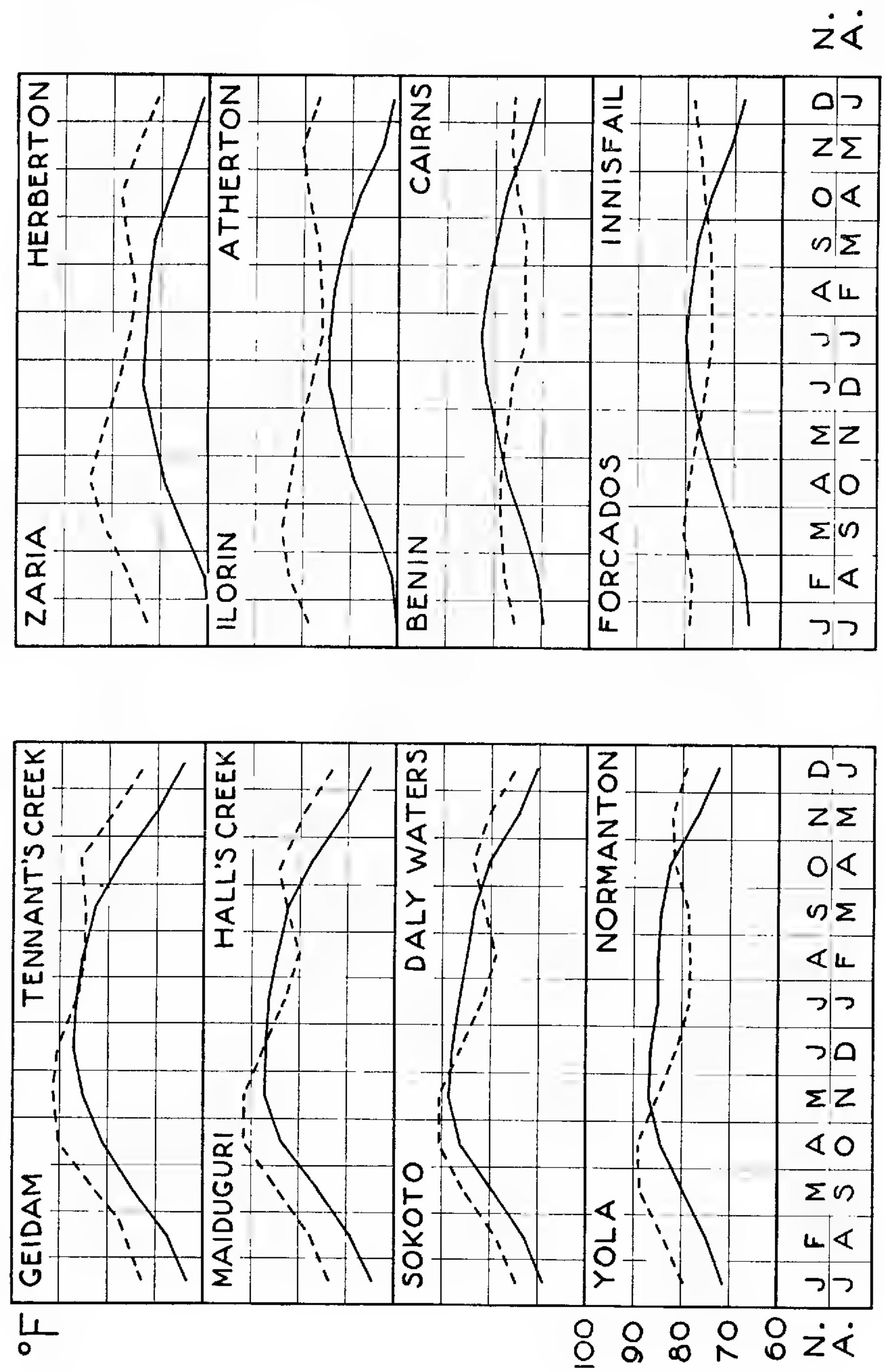

Fig. 5

Comparisons of the stations indicated in fig. 4 with respect to mean monthly temperatures. Australian records are indicated by continuous lines, Nigerian records by broken lines. The months of the year, series N. for Nigeria and A. for Australia, are suitably transposed to allow for the differences between the northern and southern hemispheres.

Conclusion

The climate of the greater part of tropical Australia may thus be said to be characterised by its seasonal character. Any system of agriculture suitable for this region must seek its counterpart in other parts of the world where such systems have been developed. West Africa has been selected for comparison as having a long tradition in this respect and of affording numerous parallels with respect to soil and climate. The areas suitable for such systems in Australia are restricted to those of fig. 1 B, in which for some period of the year the monthly ratio of rainfall to saturation deficit of 35 is exceeded, with a marginal fringe along the southern boundary. These areas will be seen to be restricted to the Kimberley coastline, to the northern part of Arnhem Land and its western settled extension and to the Cape York Peninsula. In these areas a season of five months' duration includes one month of very wet conditions, this combination probably representing the ideal conditions for high yields of most tropical crops adapted to short seasons.

Apart from these areas, the coastal belt of Queensland should be noted. The conditions here are entirely different and the length of season is much greater. The map, moreover, reveals the reason for the necessity for irrigating sugar-cane in the Burdekin delta at Ayr. An important factor which is to be noted is the great variability of the seasonal rainfall in tropical Australia. No attempt has been made to map this variability —examples only have been given. The subject is suggested as one for further study by a statistician. Further limitations to the scope for agricultural development are likely to be imposed by soil conditions in these areas. More information is required, however, before any quantitative assessment of this factor can be attempted.

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Appendix

In the appendix are given two maps to the same scale: one of Nigeria and one of the area of tropical Australia under consideration. These are intended in part as keys to the localities mentioned in the text.

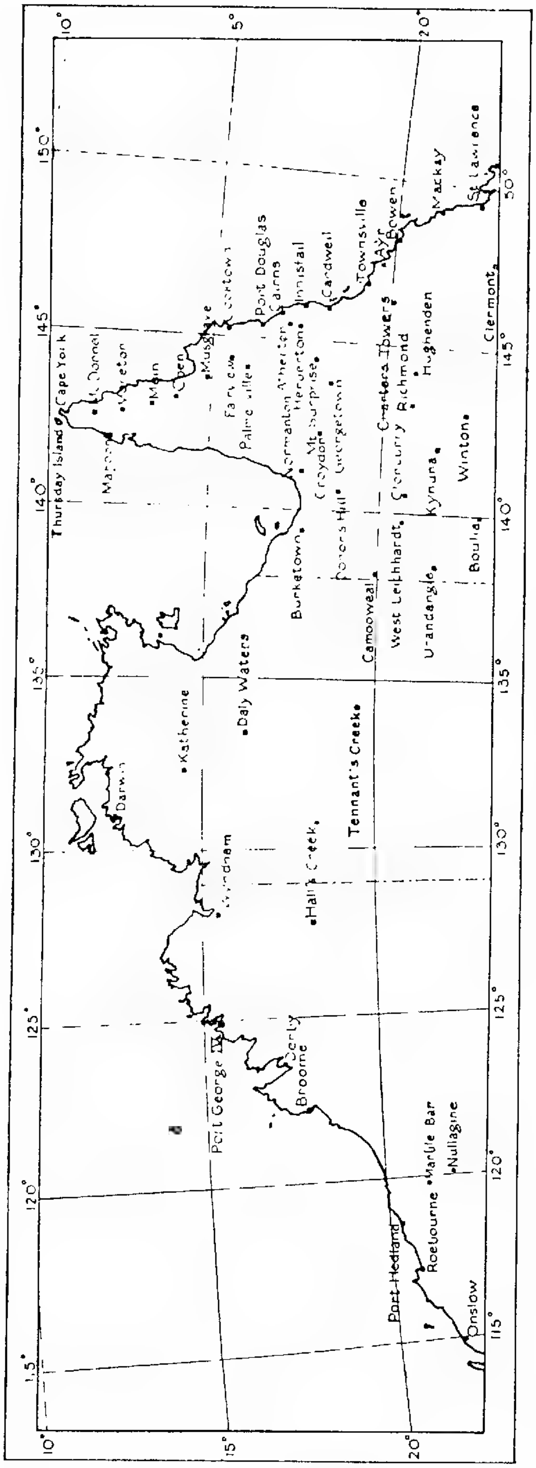

Fig. 6

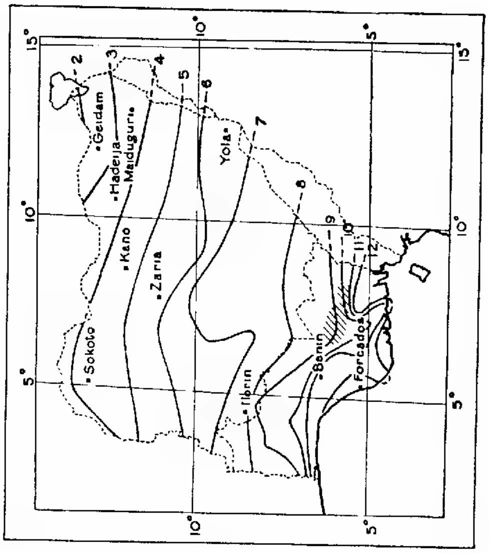

Fig. 7

Fig. 6

Map of tropical Australia indicating the stations for which the values for temperature, humidity and rainfall were used in constructing the maps of figs 7 and 8. Many additional stations are available with respect to rainfall. Temperature and humidity records are too recent to be available for Katherine.

Fig. 7

Map of British Nigeria, indicating the stations mentioned in the text with which comparisons with Australian stations have been made. Isochrones of the length of the wet season, the ratio of precipitation to saturation deficit being equal to 5 or more are also shown. The shaded area has a period of lesser rains—as was the case in the map of fig. 1A.

It may be noted that the population of Nigeria, the densest native agricultural population in Africa, is 19·93 millions. The population of Kano province is 2·44 millions with a density of 138·4 people to the square mile. Kano city itself has a population of 89,000.

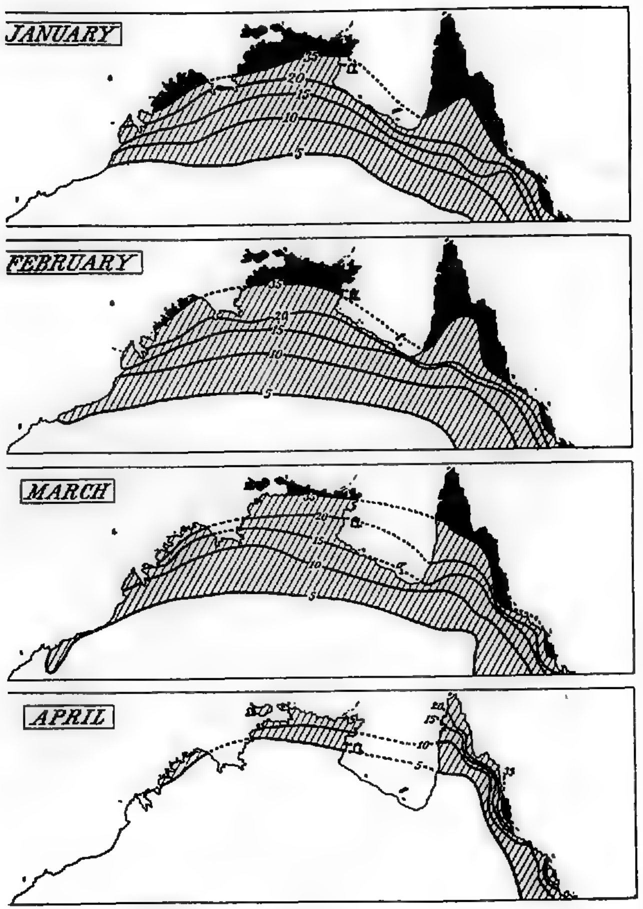

Fig. 8a

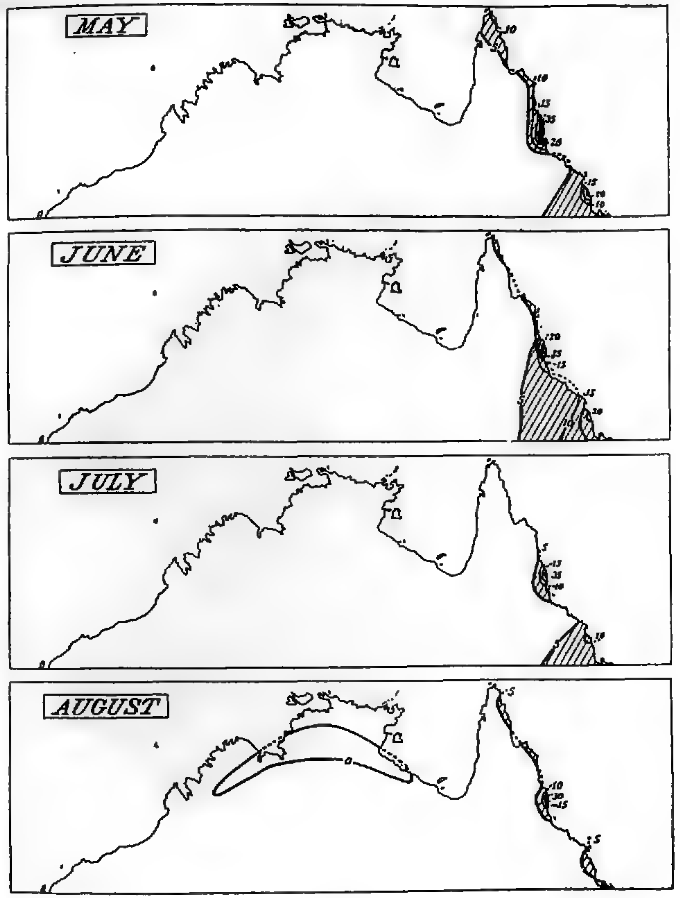

Fig. 8b

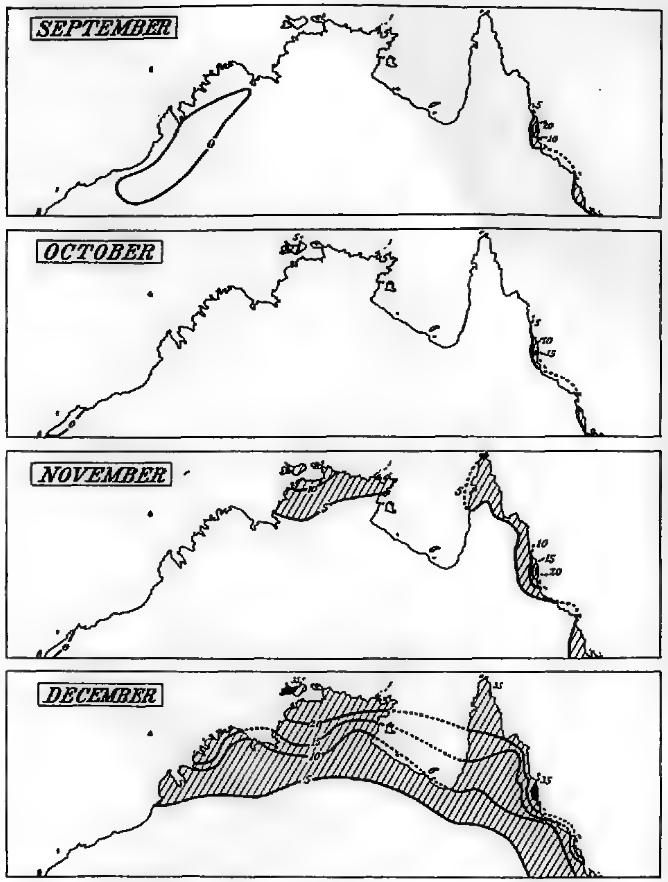

Fig. 8c

Maps of tropical Australia showing monthly isologs of the ratio of rainfall to saturation deficit. The value of 5 indicates the ratio required to keep the moisture content of the soil above the wilting point of plants; the value of 35 corresponds to that required to keep pace with evaporation from dense vegetation or from a saturated soil. The shaded areas illustrate the advance and retreat of the monsoon in tropical Australia. An absolutely rainless narrow belt of country is to be noted during the months August to November.

ABORIGINAL CRAYON DRAWINGS III
THE LEGEND OF WATI JULA AND THE KUNKARUNKARA WOMEN

BY C. P. MOUNTFORD ACTING ETHNOLOGIST, SOUTH AUSTRALIAN MUSEUM.

Summary

In August, 1935, the author was afforded an opportunity to accompany an expedition to the Warburton Ranges of Western Australia under the auspices of the Board of Anthropology of the University of Adelaide, assisted by funds from the Rockefeller Foundation. These were administered by the National Research Council.

ABORIGINAL CRAYON DRAWINGS III
THE LEGEND OF WATI JULA AND THE KUNKARUNKARA WOMEN

By C. P. Mountford, Acting Ethnologist, South Australian Museum

Plates XIII and XIV

[Read 14 July 1938]

Introduction

In August, 1935, the author was afforded an opportunity to accompany an expedition to the Warburton Ranges of Western Australia under the auspices of the Board of Anthropology of the University of Adelaide, assisted by funds from the Rockefeller Foundation. These were administered by the National Research Council.

While stationed at the base camp at Warupuju—a native water on the junction of the Elder and Warburton Creeks—the writer was able to collect drawings from the aborigines of these parts. Some of these drawings, which were executed on sheets of brown paper with red, yellow, black and white crayons, are described below.

As explained in a previous paper (Mountford, 1937C), special care was taken to avoid influencing the choice of either subject or colour. Until the aborigines became conversant with the author's wishes, the only direction given them was to make *walka* (marks) on the paper. In a few days, however, such a request was not necessary; the natives became so eager to "make marks" that the author was unable to gather all the relevant information. The supply of paper and crayons had then to be curtailed accordingly. The significance of the various symbols and the relevant legends were recorded on a sheet, together with the registration number of the native and the date. K is the symbol for the Warburton Range expedition and precedes the number of the particular native.

The drawings relate to the wanderings and exploits of the aborigines' ancestors who inhabited the surrounding country in far-off mythical times. The aborigine referred to these beings—of which there were many—as *tjukur*, or people of the dream time. A suggested parallel of this "dream time" would be that of the Creation as recorded in Genesis. The drawings obtained were, for the most part, of a sacred nature, and were not seen by the women, children, or uninitiated youths. This applies particularly to the suite under review.

In a previous paper (Mountford, 1937C) the author dealt with drawings which related to the travels and adventures of two ancestral beings, the Wati Kutjara (*Wati*—men, *Kutjara*—two). Those recorded in this paper tell of a human ancestor, Wati Jula, and a number of Kunkarunkara women. (*Kunka* or *Kunkawara*—fully developed woman).

The Ngada tribe of the Warburton Ranges, amongst whom the members of the expedition worked, is divided into two divisions, the *Tjindulakalnguru (tjindu*—sun, *nguru*—camp) (literally, those who camp or sit in the sun), and the *Wiltjalanguru (wiltja*—shade, *nguru*—camp) (those who camp in the shade), (Tindale, 1935, 171). The Watikutjara belong to the ancestral beings of the former class, and Wati Jula to those of the latter.

According to Tindale, both ancestors came from the east and travelled towards the west. The Wati Kutjara passed close to the north of Warupuju, visiting Lelele (Mountford, 1937C, fig. 2), a waterhole some ten miles north-west. In fig. 7 of this suite, Wati Jula is associated with the same locality. Similarly, the Wati Kutjara visited Julia in the distant north-east (Mountford, 1937C, fig. 12). In fig. 3, the man Jula stayed at Kapi Jukata, which was close to Julia. In fact, the place name Julia suggests some connection with the ancestor Jula.

Again, both the Wati Kutjara and Wati Jula possessed a group of women called the Kunkarunkara; with, however, the distinct difference that whereas the Wati Kutjara were the protectors of the women (Mountford, 1937C, 20), Jula seems to have always been their pursuer.

In both cases the ancestors, as well as their women, were transformed into stars, the Wati Kutjara becoming the Gemini; of which α Gemini is Mumba, the younger, and β Gemini, Kurukadi, the elder.

Jula, on the other hand, is represented in the sky by a series of stars forming part of Orion; the α and γ, *i.e.*, Betelgeux and Belectrix, being the knees, and Orion's belt, the toes. Between Jula's knees are three red stars, which represent the Kunkarunkara women whom Jula pursued with such pertinacity.

In the interpretation of the drawings, Jula's women were always referred to as the Kunkarunkara. Later on, when discussing the women depicted in the Wati Jula drawings with Pitawara, our interpreter, he said that, although they were called the Kunkarunkara, they were not the real Kunkarunkara, but only resembled them. As the Wati Kutjara were Pitawara's totem ancestors, it is quite understandable that he would not consider the women belonging to the ancestral human being of the other moiety of the tribe—even though they bore a similar name—to be the same as those of his own totemic being.

The drawings of the Wati Kutjara (Mountford, 1937C) and the Wati Jula suites have several points in common. In the Wati Kutjara legend Mountford (1937C), in fig. 16, depicts an almost identical object constructed and discarded under similar circumstances by the Wati Jula. Fig. 8 (1937C) is the mark made by the dragging of the wanigi by the Wati Kutjara; while fig. 4 of the present series is almost identical. The Wati Kutjara left two nose bones behind which turned into hills (see Mountford, 1937C, fig. 3, R and S). Wati Jula did the same thing (see fig. 9 of this paper), and two similar natural features arose. From these comparisons it is evident that each moiety of the tribe has a similar legendary story which relates to the doings of their own particular human ancestors. In both the Wati Kutjara and Wati Jula legends, the men had women who bore the same name, and were later transformed into stars; the men also became stars, and both ancestors travelled from east to west, visiting similar waterholes, all of which lie to the north of Warupuju. In many other ways, recorded in both the Wati Kutjara and Wati Jula drawings, these people had adventures in common.

A point worthy of note is the eastward direction of travel of both the Wati Kutjara, the Wati Jula and the Kunkarunkara. These routes may be those taken by the first migrating group of aborigines. Such an aspect requires further study.

Descriptions

Fig. 1 [1] illustrates Wati Jula and the Kunkarunkara women (*Kunka*—young woman) at Kapi Kurubalqua (*kapi*—water). This was drawn by K 36, a young aborigine about 20 or more years of age. Six drawings in this suite

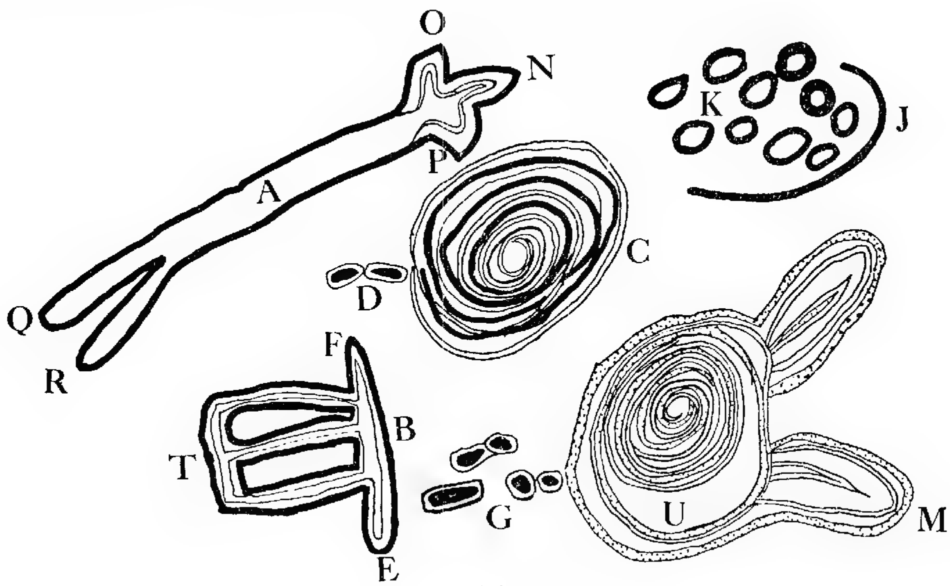

Fig. 1

were his work and all referred to the topography and legends of his tribal area. Wati Jula is shown at A, lying on his abdomen, watching the women prepare their camp at K. OP, QR and N indicates his arms, legs and head, respectively. A is now a long hill that resembles Jula's body. From this place he walked to C, where he urinated, thereby creating the waterhole Kapi Kurubalqua. Some drops of Wati Jula's urine were responsible for the small waterholes at D. B, Jabu Murlili (Jabu—hill or rock) was made where the ancestor sat down for a rest. T, and EF are the hills that rose up where his buttocks and feet rested, respectively.

[1] The colours used in this and other drawings of the present series are indicated on fig. 2.

The next stage in Jula's journeyings was from Jabu Murlili (B) to Jabu Inbunda (U). The footmarks are indicated at G. At U, the man again rested, and a similarly shaped hill appeared, U representing the depression made by the buttocks, and L and M those of the legs.

Wati Jula still had in mind the capturing of the women, and with this object in view approached them from the direction of their windbreak, J. He was unsuccessful, however; the women, seeing him coming, ran away towards the north-west, closely pursued by Wati Jula.

A point of interest in connection with fig. 1 is the dissimilarity of the two symbols, B and U, both of which are used to denote the same thing, *i.e.*, the

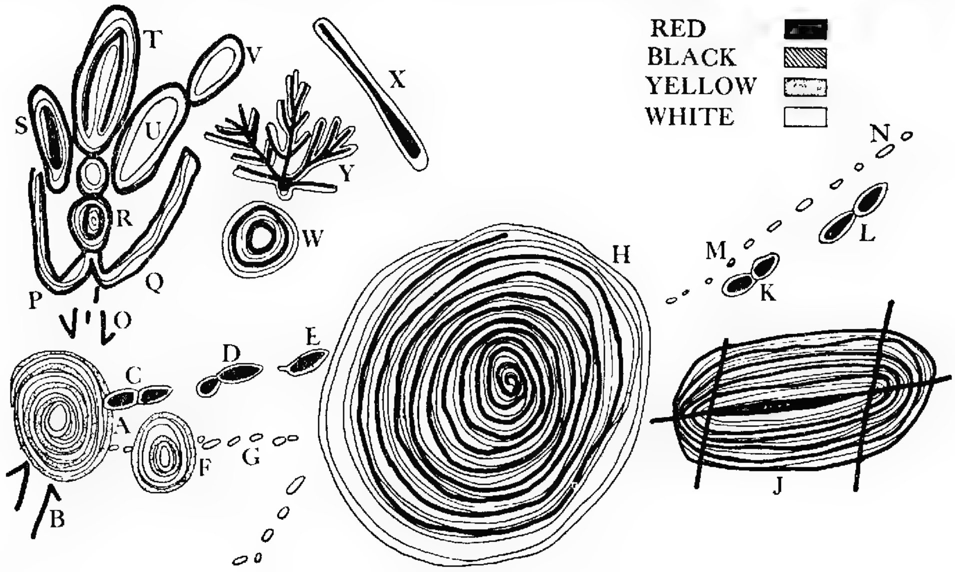

Fig. 2

impression in the sand made by the seated Wati Jula. B, is represented entirely by rectangles, and U, by more or less circular markings.

Among the Aranda (Mountford, 1937 A, 93), the U within U design has a similar significance, *i.e.*, a man's camp, or where he was seated on the ground.

Fig. 2 was also the work of K 36, and depicts the natural features created by three animal ancestors, *i.e.*, Wati Jula, Nurlu, a large mouse (unidentified) and Nuna, a snake. Starting from the upper hight-hand corner are the tracks, M, N, of Nurlu, which, judging by those shown at O, is one of the indigenous marsupials. The animal-being passed through the semi-permanent waterhole, Kapi Widjul (indicated by the large spiral H), only a short distance north of our base camp. Continuing on his journey, Nurlu travelled through rock holes, F and A to R; the former waterholes being named Kapi Ningaru. O indicates the hind feet and tail tracks of this small ancestral animal, and the small ovals at G its tracks.

Nurlu apparently gave birth to young at R (although the artist did not say so), for S, T, V and W are the young Nurlus, which, at the present day are small hills situated in the middle of a stony plain. R is now a totemic stone that represents the body of the mother Nurlu. The ground around this place is tended by the natives of that totem, who erected the wind break P, Q to assist in keeping the stone clean. R was described as a "pretty stone," similar to another totemic stone adjacent to Warupuju. In order to give some idea as to the probable appearance of R, the wallaby or *tawalpa,* totemic stone is illustrated on pl. xiii, fig. 1.

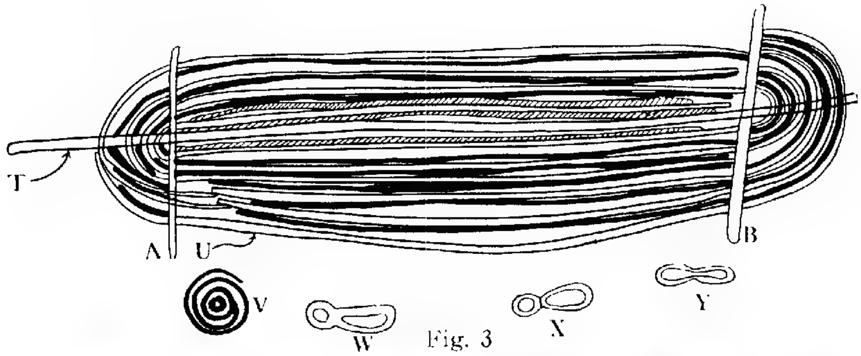

Fig. 3

Fig. 4

X is a *tali,* sandhill, Y is a *windalka,* mulga tree, and W is a semi-permanent waterhole, Kapi Kaldura, all of which features were the work of the mythical snake, Nuna.

Ancestral Wati Jula passed through this country; starting at A, Kapi Ningaru, he travelled to H, Kapi Widjul. His tracks are shown as C, D and E. While at the latter locality Jula made the waterhole and camped for the night. Here he constructed a wanigi,[2] which he left at J. It is now a large, stony hill.

Fig. 3 depicts a wanigi made by Jula. The artist, Mungalo (K 14), did not say whether it is the same as that shown on fig. 2. The middle stick T is made of a spear, on which cross pieces A, B, are fixed. String made of fur is wound in the manner shown in the drawing. W, X, and Y are the footmarks of Jula, and V a waterhole, Kapi Jakuka, adjacent to Julia. Fig. 3 is similar to fig. 16 of the Watikutjara suite (Mountford, 1937 C).

[2] A ceremonial object made of string and sticks. J is a fair representation of a wanigi.

Fig. 4 refers to a large hill, X, called Jabu Wiraruba, situated north-east of our base camp. K 14, the middle-aged artist, said that Jula came from the west dragging a wanigi with him (see fig. 3). The broad red line outlined with white across the centre of fig. 4 signifies the mark made by this object.

Although the significance of Y was not obtained, it no doubt refers to some part of the topography of the country, probably a deep valley. In fig. 9, Kapi Wiraruba is again figured, the large hill having, apparently, been created from a portion of Jula's genitalia.

Fig. 5 was the work of a young aborigine (K 52), aged about 25, called Ndanundja. The drawings illustrate some fourteen water catchments in the country north of Warupuju. Jula entered this territory—indicated on the left of the page—in company with the Kunkarunkara women. At every place along the route where the women camped for the night a waterhole appeared, *i.e.*, at P, O, M, L, K, J and I. The parallel lines that connect these places indicate the ranges of hills that rose up under the feet of Jula as he walked along in company with the women. Reading from the left, the waterholes are named thus: P, Kapi Elagudjara; O, Kapi Wunan; M, Kapi Muriga; L, Kapi Ilurumbal; K, Kapi Jurimba; J, Kapi Kunkarunkara; and I, Kapi Kunjunura. Wati

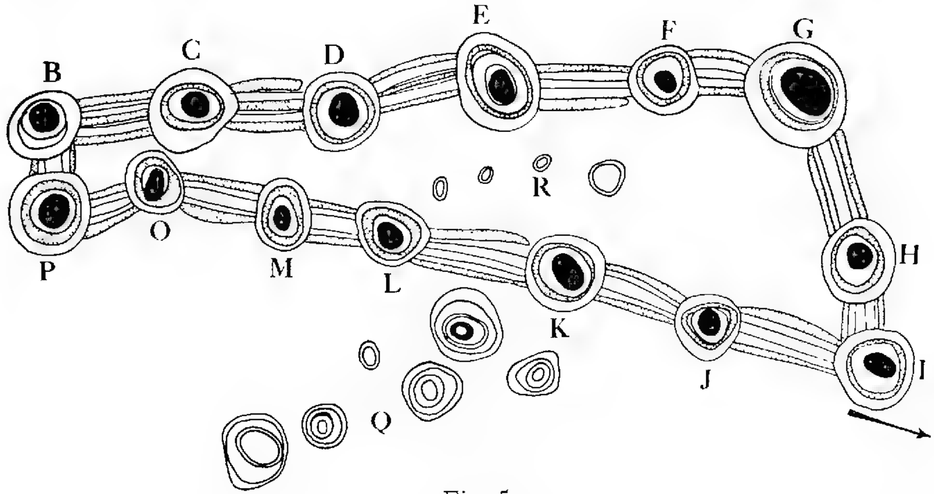

Fig. 5

Jula and the women left these parts in the direction indicated by the arrow. The meaning of the circles at Q was not given.

The upper group of concentric circles is symbolical of a line of waterholes created by Tjakobari, a mythical emu. Entering this part of the country at I, a waterhole was created at every camping place, *i.e.*, at H and G, both called Kapi Ewari; F, Kapi Nurien; E, Kapi Tinkulmungata; D, Kapi Watundja; C, Kapi Widjul, a place north-west of our camp (see H, fig. 2); and B, Kapi Nulungari. The parallel lines connecting these localities are hills that rose up from the tracks of the emu.

A comparison between this drawing and that in fig. 2 shows that Kapi Widjul was created by two ancestors, *i.e.,* Jula in fig. 2 and the emu Tjakoberi in fig. 5. As the routes of the wanderings of the totemic ancestors cross the country in many directions, it is not surprising that more than one totemic group would claim that some more important waterhole or natural feature was the work of their particular forbear.

The particularly decorative sheet, fig. 6, was produced by an aged aborigine, K 3, named Tolaru. The numerous symbols with which the old man laboriously filled the sheet represent a number of Kunkarunkara women travelling from Kapi Lelele, A, B. These waterholes, created by the Kunkarunkara, were situated some ten miles north-west of Warupuju. The women were all moving toward

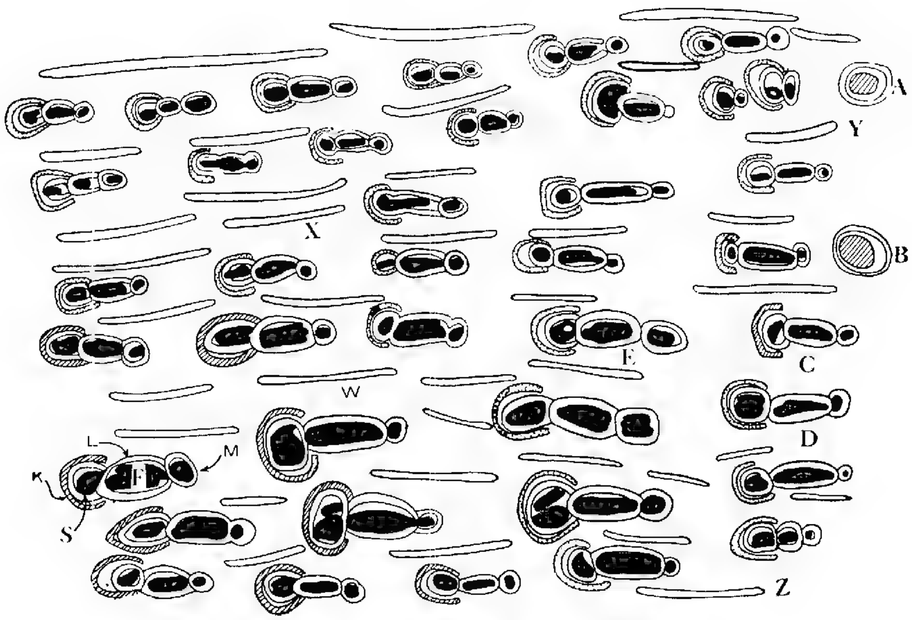

Fig. 6

the west, carrying their digging sticks, *wana,* with them. K 3 was not aware of their destination, but only knew that in far-off mythical times they had travelled through the sandhill country north of our camp. The figures, such as C, D, E, F and so on, are the women who, as they travelled, trailed their digging sticks in the sandy soil; W, X, Y and Z signify these marks. At F, the details of the women themselves are shown. S, is the head; L, the body; M, the buttocks; and K, the hair string bound around their hair. Tolaru made no reference to Wati Jula. Mountford (1937 C, fig. 2) records a drawing, also the work of K 3, that relates to one of the Watikutjera at Lelele.

An elderly, one-eyed aborigine named Jandjibalana (K 24) made the drawings of fig. 7. These illustrate a number of waterholes, hills, creeks, and springs made by Wati Jula. The latter is indicated at B. Entering this area in the direction of the arrow on the lower left-hand corner, the ancestor made C, Karu Wanba (*karu*—creek). In this creek there is good spring water. From there he travelled through F, G, H, J, K, S, L, M. He created the large hill N, Jabu Pukuna, and the three waterholes P, Q, and R. Starting from F, the names of the localities in which water can be found are: F, Kapi Dudina; D and H are unnamed, H being only a small catchment; J, Kapi Widjul (see fig. 5); K, Kapi Tjilida. L, M and P and Q were unnamed, except that Q was specified as a large waterhole situated in a northerly direction. R was called Kapi Tarkulkura. The departing tracks of the ancestor appear in the upper right-hand corner at O.

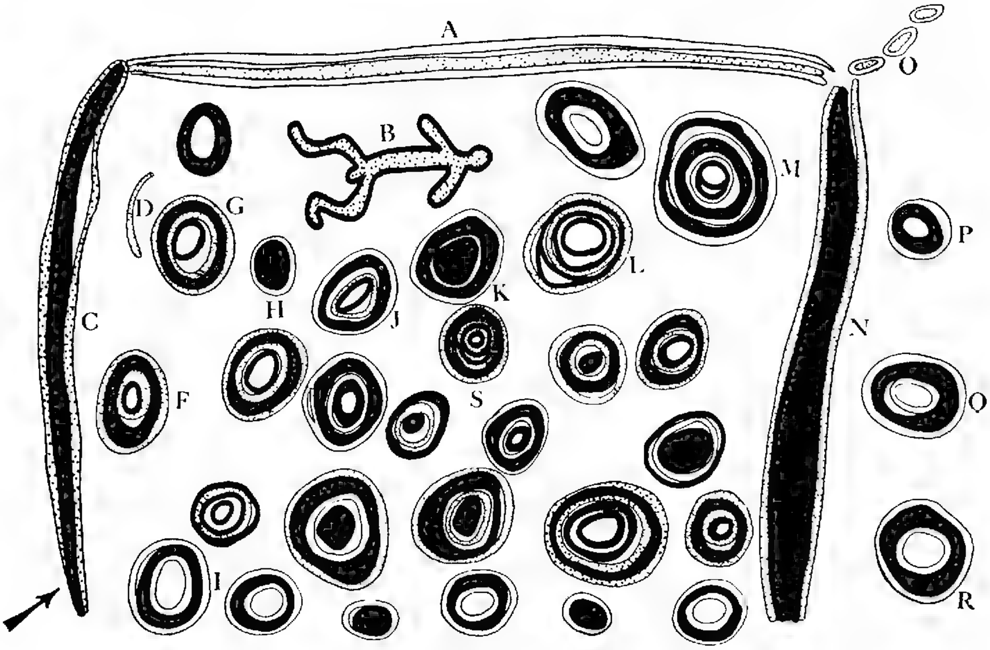

Fig. 7

The significance of the groups of concentric circles in the lower part of the sheet was not obtained, but it is reasonable to suppose that these have a similar meaning to those already indicated. Wati Jula did not meet anyone whilst in this locality.

Fig. 8 was drawn by Mungalu (K 14), an elderly aborigine who produced several unusual drawings, particularly those dealing with the Wati Kutjara (Mountford, 1937 C, pl. i). In this case the drawing shows the waterholes made by three beings, *i.e.*, the Kunkarunkara women, Tjidowri, a snake, and Nirunba, a small unidentified bird. The bird itself does not appear to have travelled about, but created the hills R, S. G. H, O, J, and C. Q, Kapi Wilkurul, a large rock hole, is also his handicraft. This ancestral bird lives at the present day in the hills.[3] The Kunkarunkara created hills D, K and P, but Mungalo, the artist, was not aware of the women's destination. A mythical snake, Tjidowri, made Kapi Kamina, E, and Kapi Ngunduluga, L and M.

Fig. 9 was the work of K 36 and depicts an area of his own tribal country. Its natural features were created when Wati Jula came across the camp of the Kunkarunkara women, with whom he wished to co-habit. His advances, however, were repulsed.

The series of small circles at U and W, which are now low rises, are representations of the women. A large hill, A, Jabu Wilraburuba, is the transformed

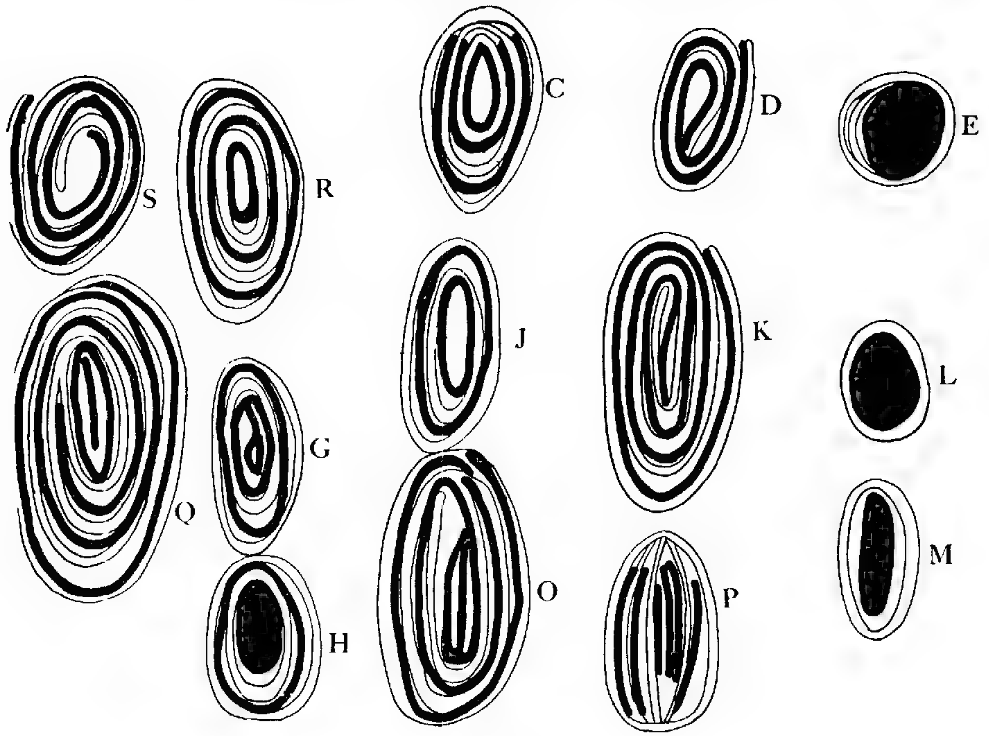

Fig. 8

wibu (phallus) of Wati Jula. F are the pubic hairs, and G a hill called Jabu Wiraruba (see fig. 4).

Some of the symbols shown to the right of A (Jabu Wilraburuba), in the camp of the Kunkarunkara, are of interest. The A-shaped marks at T, superficially resemble T and W of fig. 1; and, being associated with a camping place, may represent a seated aborigine. The semi-circular figures adjacent to U, the enclosed circles, and the parallel straight lines at X, are somewhat like sketches of camps

[3] This particular belief regarding ancestral beings living in waterholes was met with repeatedly during our work with this tribe. Spencer and Gillen (1904, 252) give details of an ancestral snake who lived more or less permanently in the waterhole. The bird mentioned in fig. 8 is the first case observed by the author in which an ancestor still lives in the hills.

made by the natives of these parts. In this case the semi-circular lines represent the windbreak, the circle within, the woman, and the parallel straight lines, the sticks of firewood laid in readiness for the evening fires.[4] A number of natural features was created by Wati Jula. R, one of Jula's camps, is now a large hill. By the same agency S, Kapi Wunan (see fig. 5), was created. O and Q are hills, Jabu Ngenga, previously the nose bones left behind by the ancestor.[5] D is recorded as Windulka. This is the aboriginal name for the mulga tree *(Acacia aneuris)*, but whether D represents such a tree, or is a natural feature bearing that name, was not ascertained.

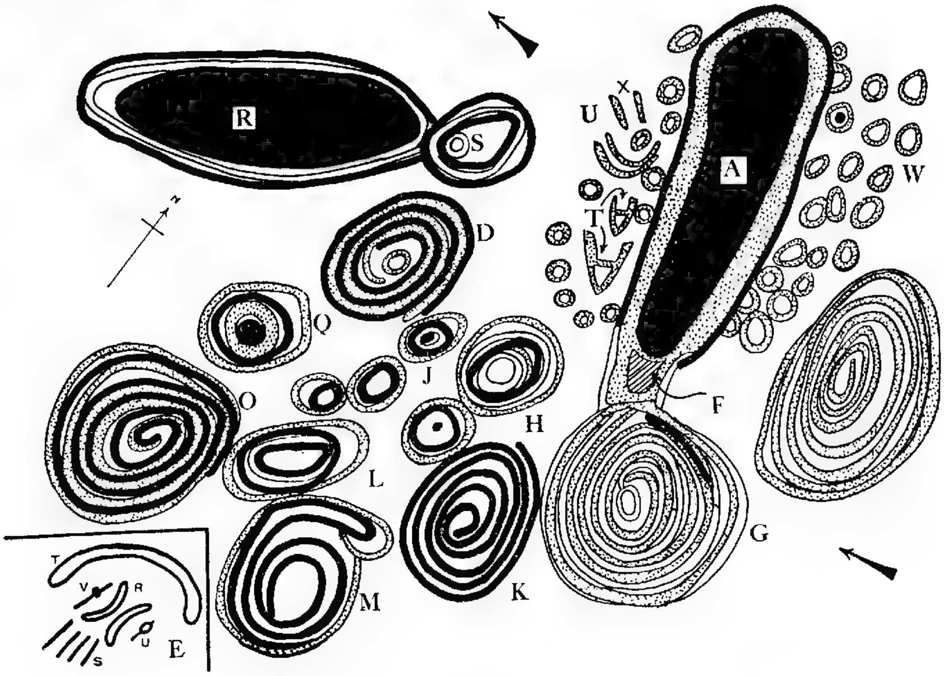

Fig. 9

Concentric circles, H, J, K, and M, are hills created by the mythical women, and L a waterhole.

Jula entered these parts from the lower right (see arrow), and after the escape of the Kunkarunkara followed them in the direction of the north-west. The arrow on the top indicates the direction.

Figs. 10 and 11 are of particular interest in that they show, to the aborigines' satisfaction at any rate, how the parallel lines of sandhills, which are so characteristic a feature in the western desert country of Central Australia, came into

(4) A copy of an aboriginal sketch of a native camp is drawn in miniature at E. T, in this example, is the windbreak behind which the natives sleep. R, are those people on either side of the fires U V, across which a log of wood is laid. The spare firewood, by which the fire would be replenished at night, is indicated by the straight lines at S.

(5) A similar incident happened in the Wati Kutjara legend (Mountford 1937 C, R. and S, fig. 3).

being. The area depicted in fig. 10 belonged to K 36, and the drawing is his work.

The groups of small circles at A are the Kunkarunkara women camped behind a windbreak, R. Parallel lines, E, are the tracks made by the women as they approached their camp at A. These tracks are now a thick growth of trees.

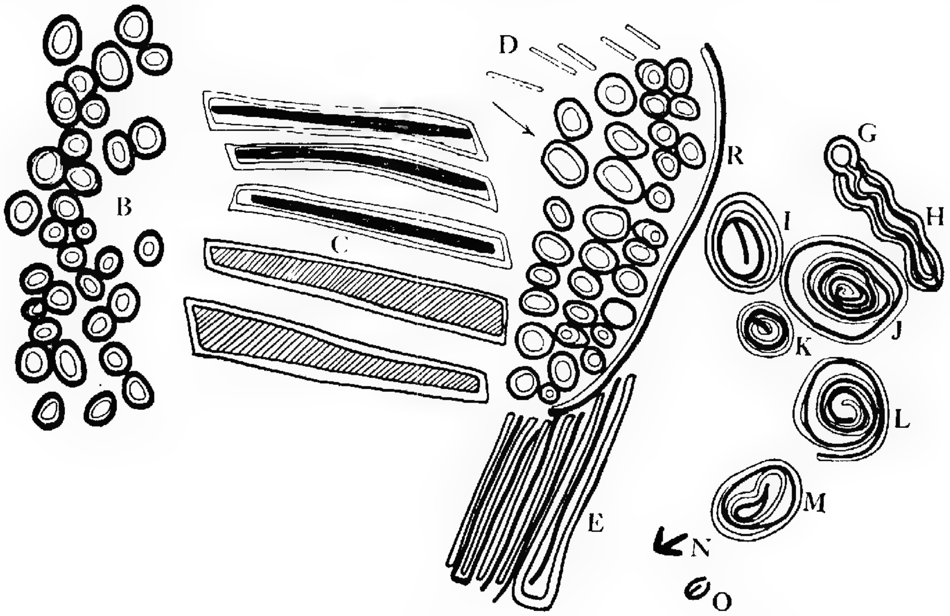

Fig. 10

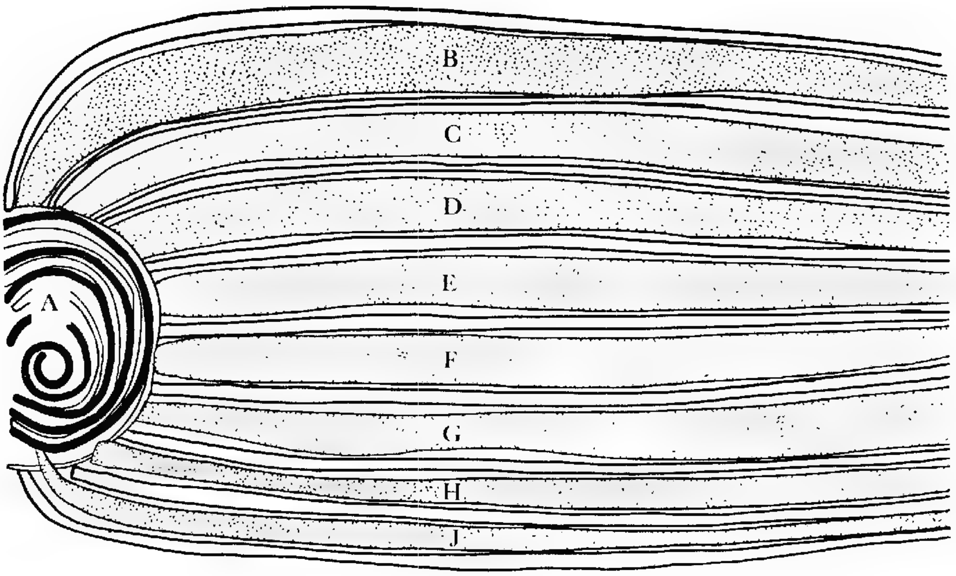

Fig. 11

While at this place, which is close to a waterhole called Mamai, the ancestral women played and danced from A to B, the gutters produced in the sand by their feet forming the spinifex covered flats between the present lines of parallel sandhills. The white outer lines of the long rectangles, C in fig. 10, are those flats, and the inner yellow or black lines, the intervening sandhills.

By good fortune, the author, while at Warupuju, witnessed a similar dance to that performed by the mythical Kunkarunkara women. At the commencement of the circumcision ceremony the women perform a short dance, *nangbi,* in which they move along abreast, shuffling their feet in a peculiar manner (pl. xiii, fig. 2). The resulting marks made in the sandy soil resemble, in a remarkable manner, the alternate swales and ridges of the sandhill country. A photograph

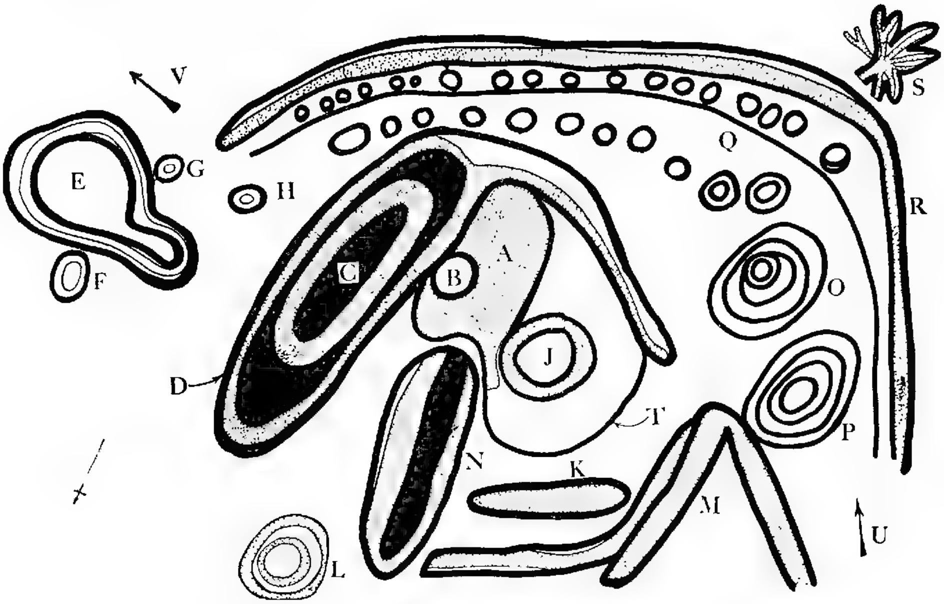

Fig. 12

of the tracks made on this occasion (pl. xiv, fig. 1), compared with an aerial view of the actual parallel sand ridges[6] (pl. xiv, fig. 2), illustrates the similarity between the tracks of the women and the sandhills.

A similar legend to fig. 10 is connected with fig. 11. In this case the Kunkarunkara made the hill, A (Jabu Jenabunda), and then danced away backward toward the west. The white lines are the marks made by her feet, now the crests of *ta'li* (sandhills), while the space coloured yellow, *i.e.*, B, C, D, and so on, the *bila* (spinifex covered flats), between them.

Fig 12 was also the work of K 36, and the incidents here depicted centre around the waterhole, Meitika, situated in the artist's tribal area.

[6] This photograph, kindly lent by Dr. C. T. Madigan, was taken over the Simpson Desert, Central Australia, from the height of 4,000 feet.

At this place the ancestral women camped; the series of circles adjacent to Q indicating the place where they seated themselves. R is a long hill, Jabu Meitika, that rose out of the ground to form a windbreak for the resting women.

It was in the *bulba* (cave), at Meitika, that the ancestral women prepared a cake by grinding grass seeds. Previous to this the floor of the cave was level, but since that day a hole exists, worn by the women in their efforts to reduce the grass seed into flour. This depression is now filled with water, and forms Kapi Meitika, one of the well-known supplies of the neighbourhood. T is the outline of the cave. When the women had made the damper (or cake), they placed it at N. From notes provided by Mr. N. B. Tindale, it appears that Wati Jula surprised the women at this place, and was successful in catching one while she was preparing the cake for cooking. He crept towards another sleeping woman, but, being too eager, slipped and took the skin off his shins. This misfortune allowed the woman time to escape. Possibly all the women fled at the same time, for the damper, the bottom grinding stone, and the wooden dish that contained the grass seed were left at N and D. The grinding stone and dish were transformed into a large hill at the back of Meitika, the bottom portion being the grinding stone, the upper the wooden dish, while the damper is now a hill that slopes downward toward the waterhole.

The women entered this country from the direction of U (lower right-hand corner) and travelled in a south-easterly direction, V. Various other natural features are depicted on this sheet. K, M, O, P are hills. S is a mulga, and L an unidentified tree called Pulguru. F, G, and H are small waterholes, while E, Kapi Purdi, is a large rock hole inside of a cave.

Discussion

The drawings of the Wati Jula legend are somewhat similar in design and general meaning to those of the Wati Kutjara, and, as in the case of the latter, the designs, colours used, meaning of the various symbols, and the ages of the artists, were analysed and fully discussed, no good purpose would be served in repeating that discussion.

Of the present material, six out of the twelve drawings were the work of one man, K 36, who was of the Wati Jula totem. The drawings executed by this aborigine, figs. 1, 2, 3, 9, 10 and 12, most of which relate to his own tribal area, contain much more detail and interest than those produced by other men, who were obviously not as conversant either with the legend of Wati Jula or the topographical features created by him. All the drawings of K 36 referred to his country, and the doings of his ancestor. It is difficult for the average person to appreciate an aborigine's intense interest in and knowledge of his country; but when we consider that every hill, every creek, every large tree, every waterhole is, in the mind of the native, created by semi-human beings who were the ancestors of his tribe, we can better understand the intimate association between the native and his country. This understanding and affection for his tribal area was strongly exemplified in Pitawara, our interpreter.

While on our outward journey we passed through an area of drifting sand-hills and spinifex-covered flats, which, from the European's viewpoint, could hardly be less inviting. Yet Pitawara, turning to one of the members of the expedition, remarked, "This good fellow country, this my country." Here he pointed out, with obvious pleasure and pride, the creeks made by the Wati Kutjara, his own forbears, and told us of the doings of his and other ancestral beings who created the few natural features that the country possessed. To him, this barren, uninviting area was full of interest because of the adventures and exploits of the mythical progenitors of his tribe.

A remarkable example of the association in the native's mind of incidents of the present day with those of the "dream time" is shown in the legend that explains the existing parallel lines of sandhills as the marks left in the ground by the mythical women when they performed the ceremonial dance (see pl. xiv, figs. 1 and 2). Similarly, in text fig. 12, the likeness of the hill at Meitika to a wooden carrying dish resting on the lower grinding stone (a common enough sight in any native camp), no doubt suggested the first part of the myth. Subsequently, the other details would be built up concerning the spot, until today we meet the legend in its present form.

Summary

This paper records twelve crayon drawings that relate the exploits of a mythical human being, the Wati Jula, and a group of women, the Kunkarunkara. The similarity between this legend and that of the Wati Kutjara, as recorded in a previous paper, the aborigine's relation to his own totemic area and the possible source of such legends are discussed.

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Mountford, C. P. 1937b Trans. Roy. Soc. S. Aust., 61, 236-240

Mountford, C. P. 1937c Record of S. Aust. Mus., 6, (1), 5-28

Spencer and Gillen 1904 Northern Tribes of Central Australia, 252

Fig. 1
Totemic Tawalpa (Wallaby) Stone, Warupuju, Warburton Ranges, Western Australia

Fig. 2
Women dancing Nangbi dance at circumcision ceremony, Warupuju, Warburton Ranges, Western Australia

Fig. 1
Gutters made in ground by feet of women when performing Nangbi dance at circumcision ceremony, Warburton Ranges, Western Australia

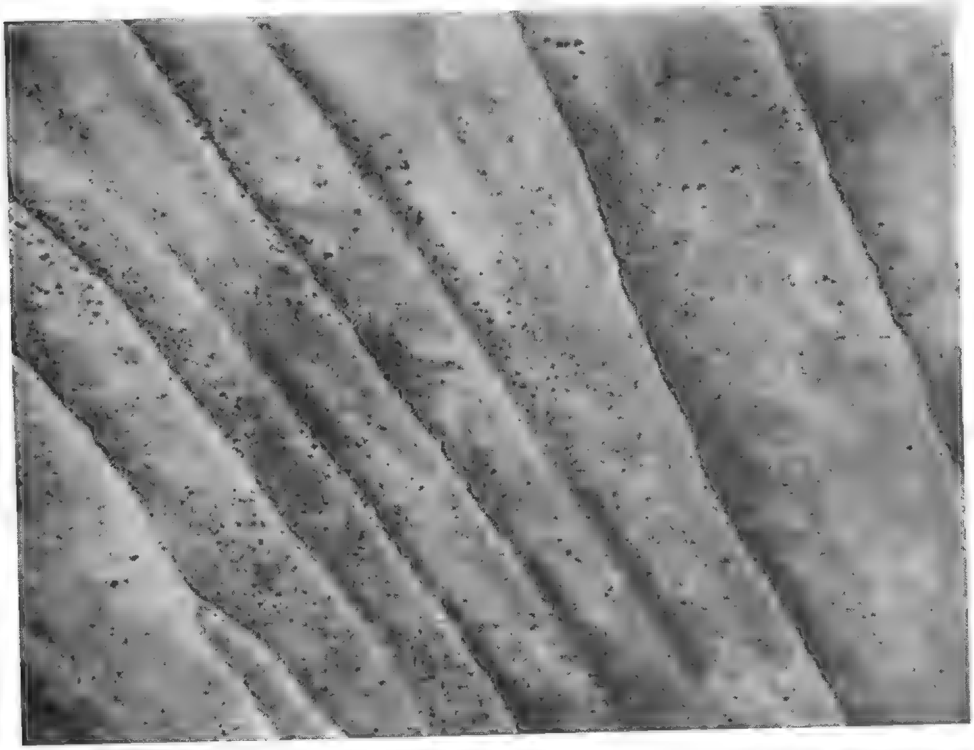


Fig. 2
Parallel sand ridges, Simpson Desert, 4,000 feet

CAMBRIAN AND SUB-CAMBRIAN FORMATIONS AT PARACHILNA GORGE

By D. MAWSON D.Sc., F.R.S.

Summary

The occurrence at Parachilna Gorge of Cambrian limestone with well preserved *Archaeocyathinae* fossils has long been known [Howchin, 1922 and 1925]. In the papers cited, Howchin has accepted as of Cambrian age a great thickness of beds underlying the fossiliferous Cambrian horizon. The evidence available appears to indicate that *Archaeocyathinae* of our beds are indicative of a Lower Cambrian age. This assignment is in accordance with David's views [Sir Edgeworth David, 1932], which are based on the findings of Dr. F. W. Whitehouse. As there is in the Flinders Range an immense thickness of unfossiliferous strata below the *Archaeocyathinae* horizon, it would appear probable that such are all Pre-Cambrian with the exception of a very thick arenaceous series which immediately underlies the *Archaeocyathinae* – containing limestone series, and with which it appears to be conformable wherever I have examined it. I am adopting this interpretation, which seems the most reasonable unless, and until, definite Cambrian fossils are discovered at a lower horizon. For the present, the beds lying immediately below this quartzite will be referred to as sub-Cambrian.

CAMBRIAN AND SUB-CAMBRIAN FORMATIONS AT PARACHILNA GORGE

By D. Mawson, D.Sc., F.R.S.

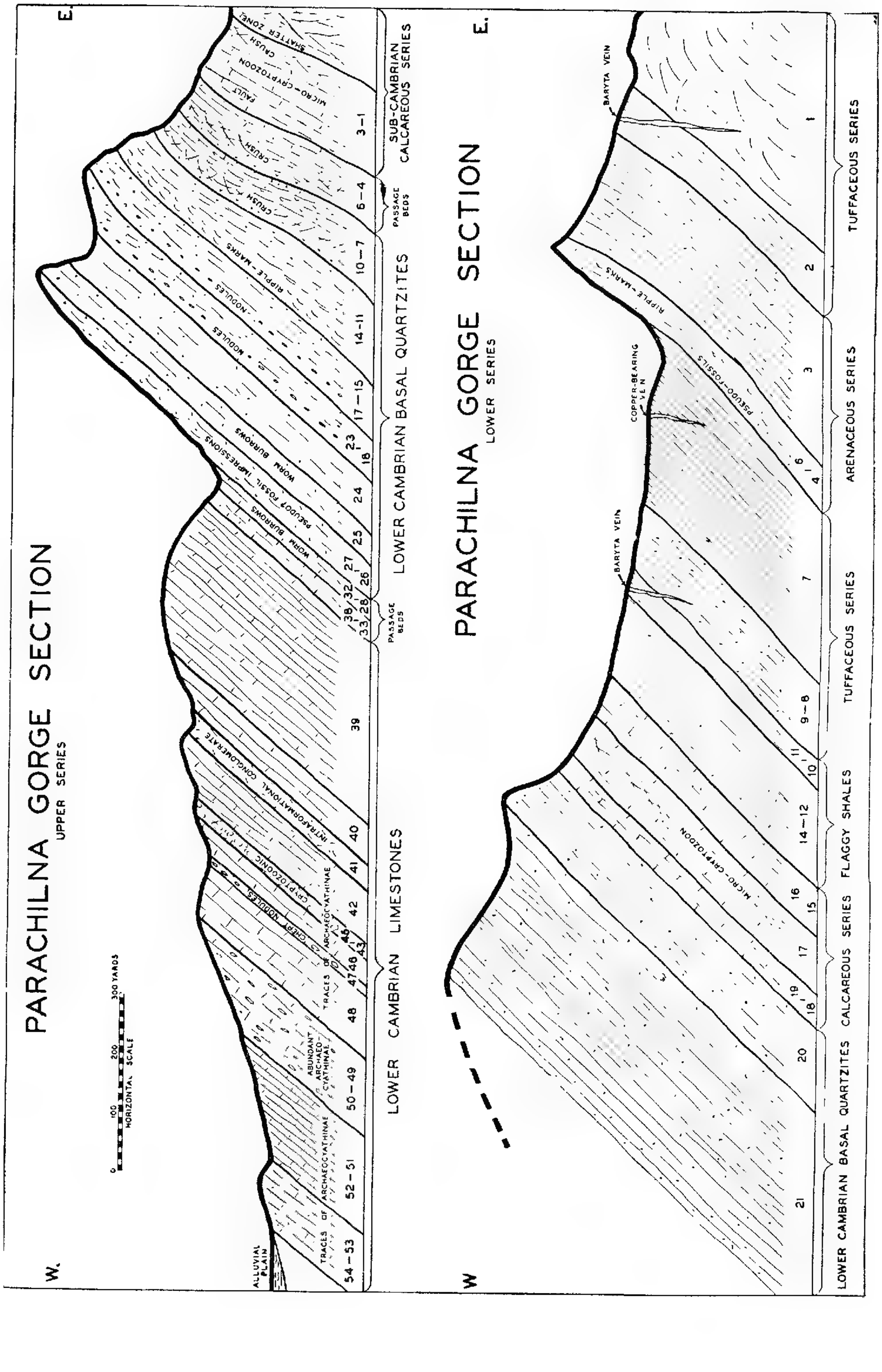
[Read 11 August 1938]

The occurrence at Parachilna Gorge of Cambrian limestone with well-preserved *Archaeocyathinae* fossils has long been known [Howchin, 1922 and 1925]. In the papers cited, Howchin has accepted as of Cambrian age a great thickness of beds underlying the fossiliferous Cambrian horizon. The evidence available appears to indicate that *Archaeocyathinae* of our beds are indicative of a Lower Cambrian age. This assignment is in accordance with David's views [Sir Edgeworth David, 1932], which are based on the findings of Dr. F. W. Whitehouse. As there is in the Flinders Range an immense thickness of unfossiliferous strata below the *Archaeocyathinae* horizon, it would appear probable that such are all Pre-Cambrian with the exception of a very thick arenaceous series which immediately underlies the *Archaeocyathinae*-containing limestone series, and with which it appears to be conformable wherever I have examined it. I am adopting this interpretation, which seems the most reasonable unless, and until, definite Cambrian fossils are discovered at a lower horizon. For the present, the beds lying immediately below this quartzite will be referred to as sub-Cambrian.

Howchin [1925, 22] states that "no occurrence of fossiliferous Cambrian age is known to exist between Wilson and Parachilna, a distance of 65 miles." Nevertheless, outcrops of *Archaeocyathinae* limestone do occur over the greater part of this length. Wherever I have examined outcrops of *Archaeocyathinae* limestone in the Flinders Range area, it is found always to overlie with apparent conformity a great quartzite horizon, which I am accepting as the basal formation of the Lower Cambrian of South Australia. This is the quartzite of the range to the west of Wilson, of the Elder Range, of Wilpena Pound, of the Aroona Range, and of the Chase Range. It is, in fact, the greatest single feature of the Flinders Range. As this quartzite is responsible for the physiographic feature known as Wilpena Pound and other pound formations in the Flinders Range, I propose that it be designated the "Pound Quartzite." Thus the Pound Quartzite is accepted as the base of the true Cambrian of the Flinders Range.

I have made many traverses in the Flinders Range establishing the above contention, but only one, that across the strata at Parachilna Gorge which illustrates the relation of the beds, is included herewith. Other sections and an account of the Cambrian and sub-Cambrian beds as far down as the Sturtian tillite horizon will be published shortly.

Howchin [1922] has shown that the Flinders Range in the neighbourhood of Parachilna Gorge is composed of a thick series of beds arched over Blinman, which is located in the centre of the Range, and, on either flank, dipping down steeply beneath the plains bordering Lake Torrens on the west and Lake Frome



PARACHILNA GORGE SECTION
UPPER SERIES
W.
E.
0 100 200 300 YARDS
HORIZONTAL SCALE
ALLUVIAL PLAIN
TRACES OF ARCHAEOCYATHINAE
ABUNDANT ARCHAEOCYATHINAE
TRACES OF ARCHAEOCYATHINAE
CHERT NODULES
CRYPTOZOONIC
INTRAFORMATIONAL CONGLOMERATE
WORM BURROWS
PSEUDO FOSSIL IMPRESSIONS
WORM BURROWS
NODULES
NODULES
RIPPLE-MARKS
CRUSH
CRUSH
FAULT
MICRO-CRYPTOZOON
CRUSH
SHATTER ZONE
54-53
52-51
50-49
48
47
46
45
43
42
41
40
39
38
33
32
28
27
26
25
24
23
18
17-15
14-11
10-7
6-4
3-1
LOWER CAMBRIAN LIMESTONES
PASSAGE BEDS
LOWER CAMBRIAN BASAL QUARTZITES
PASSAGE BEDS
SUB-CAMBRIAN CALCAREOUS SERIES
PARACHILNA GORGE SECTION
LOWER SERIES
W
E.
MICRO-CRYPTOZOON
BARYTA VEIN
COPPER-BEARING VEIN
PSEUDO-FOSSILS
RIPPLE-MARKS
BARYTA VEIN
21
20
19
18
17
16
15
14-12
11
10
9-8
7
6
4
3
2
1
LOWER CAMBRIAN BASAL QUARTZITES
CALCAREOUS SERIES
FLAGGY SHALES
TUFFACEOUS SERIES
ARENACEOUS SERIES
TUFFACEOUS SERIES

on the east. He thus explains the location of *Archaeocyathinae* limestones skirting the Range on either flank but absent in the central region. However, though fossils were absent, he regarded all the formations of the central area as Cambrian.

The sections submitted herewith, completed in 1936, traverse the fossiliferous Cambrian formation on the west flank of the Range and extend some distance below. The first section was selected over suitable ground to illustrate the nature and sequence of the fossiliferous Cambrian beds. The second section is a traverse across a belt of sub-Cambrian strata lying immediately below the fossiliferous Cambrian.

Marble, rich in *Archaeocyathinae,* occupies a limited area at the entrance to the Gorge, but at that point the succession of the beds is disturbed by faults. Accordingly, the section of the upper beds, illustrated herewith, was run across the line of strike (which trends about 10 degrees west of true north) at a point about a mile north of the Gorge entrance. There the main body of the quartzite and the overlying limestones are not seriously disturbed by dislocations. However, in this section the sub-Cambrian beds are badly shattered and dislocated. Consequently, only the upper portion of these is included to show general relationship with corresponding beds well illustrated in the second section.

This second section was run across the strike on an approximately east to west line at about one mile to the south of the Gorge entrance. Actually, the eastern extremity of the section was close to the Blinman road at a point about four miles by road towards Blinman from the Gorge entrance. At this spot the beds immediately underlying the Pound Quartzite are undisturbed by dislocations until the eastern limit of the section is reached.

The tabulated data below give details of 54 divisions recorded in the upper section, and 21 divisions in the lower section. It will be seen that two horizons of chocolate-coloured tuffaceous shales are recorded in the sub-Cambrian included within this purview.

In the limestones immediately underlying the Pound Quartzite a band characterised by what is referred to as micro-cryptozoön structure, is recorded in both sections. This is a fine mesh-like fossil or pseudo-fossil structure, which will be discussed in another publication dealing with algal fossils and pseudo-fossils of the Cambrian and Pre-Cambrian of the Flinders Range.

A feature of the Pound Quartzite is, that at several horizons in the formation the weathered face is studded with nodules as a result of the superior hardness of the cementing material in clots distributed through the stone. The nodular or "clot" feature of this quartzite has been observed at widely separated localities in the Flinders Range.

The Cambrian calcareous series in this area has been extensively re-crystallized and partially dolomitised in some places. As a result, the fossil forms have been largely obliterated. Silicification, usually in irregular patches, is evidenced in these limestones. In one horizon it is in the form of large chert nodules. Elsewhere, it is in small branching or honeycomb-forms ramifying through the marble.

The upper limit of the Cambrian beds is not reached in this section, being lost to sight beneath the alluvial accumulations of the plains. The total thickness of Cambrian strata illustrated amounts to about 3,500 feet of a calcareous formation, and 1,500 feet of a basal quartzite. This latter, however, is intersected in its lower portion by crush and faulting, and may, therefore, be short of the true thickness of the Pound Quartzite.

The sub-Cambrian beds shown are merely a portion of a more extensive series which stretches away towards Blinman. Included here is a total of about 3,800 feet, which represents only the topmost formations of this series.

Section across Lower Cambrian Beds at Parachilna Gorge

Lower Cambrian Limestones

54 230 ft. of calcareous sandstone and sandy limestone. The sand grains are well rounded. *Archaeocyathinae* fossils noted.

53 115 ft. of flaggy, siliceous, arenaceous beds, ranging from sandy limestones to greywacke. Shallow water features exhibited, including current bedding.

52 333 ft. of dolomitic limestone of a granular texture. The rock has suffered re-crystallization. To a minor degree also it has been subjected to silicification. Traces of *Archaeocyathinae* still recognisable.

51 172 ft. of granular, dolomitic limestone. Traces of *Archaeocyathinae* observed at intervals throughout this section. Near the upper limit is an horizon much richer in these fossils.

50 213 ft. of massive, granular, dolomitic limestone through which *Archaeocyathinae* are distributed.

49 180 ft. of limestones with abundant *Archaeocyathinae*. Silicification appears in small, irregular, disseminated patches.

48 336 ft. of re-crystallized, granular, dolomitic limestone; indefinite markings.

47 22 ft. of granular, re-crystallized limestone with some faint indications of *Archaeocyathinae*. Dark-coloured chert nodules are sporadically distributed through this bed. Dip, 50° to the west.

46 138 ft. of granular (part sandy) limestone. No *Archaeocyathinae* observed.

45 21 ft. of massive limestone with traces of *Archaeocyathinae*.

44 57 ft. of granular, dolomitic limestone with some silicification. Faint traces of *Archaeocyathinae*.

43 12 ft. of limestone with cryptozoönic banding and minor silicification distributed through it.

42 267 ft. of re-crystallized, granular limestone with traces of *Archaeocyathinae*. Dip, 50° to the west.

41 121 ft. of re-crystallized, dense limestone. Some bands of intraformational conglomerate. Dip irregular in part, due to wavy folding.

40 192 ft. of buff-coloured, dense limestone, oolitic in part. A faint trace of *Archaeocyathinae* noted in one place. Rounded sand grains embedded in the limestone of some beds.

39 918 ft. of massive, flaggy and oolitic limestones.

38 32 ft. of argillaceous limestones and shales.

37 7 ft. of coarse oolitic limestones. Diameter of oolitic spheres about 6 mm.

36 34 ft. of impure limestone.

35 2 ft. of silicified oolite.

34 30 ft. of sandy limestone.

33 3 ft. of coarse oolitic limestone.

3,435 ft. total thickness of exposed beds.

Passage Beds

32 23 ft. of flaggy, impure limestone.

31 23 ft. of calcareous shales with abundant worm burrows.

30 3 ft. of ferruginous flaggy sandstone.

29 21 ft. of sandy limestone.

28 34 ft. of chocolate-coloured, sandy shales with well-preserved worm casts.

104 ft. total thickness.

Lower Cambrian Basal Quartzite

27 123 ft. of saccharoidal quartzite, for the most part coloured white and of medium grain size. Fossil impressions resembling brachiopod or bivalve form, but probably merely impressions of clay galls. Dip, 50°, and strike 10° to the west of true north. For the most part massive, but with some indication of bedding planes and with occasional current-bedding. In thin section, this bed is seen to be composed almost entirely of angular quartz grains.

26 50 ft. of flaggy sandstone. Dip, 45° to the west.

25 157 ft. of soft reddish sandstone with worm burrows.

24 252 ft. of reddish-coloured, flaggy sandstone. Grains well rounded in some beds. Current-bedding noted.

23 55 ft. of softer sandstone with more firmly cemented nucleii distributed through it. These "clots" stand out in relief on the weathered face.

22 15 ft. of chocolate-coloured sandstone, composed mainly of very fine grains in which are embedded scattered grains of a larger size.

21 90 ft. of chocolate-coloured beds. More massive beds of hard quartzite of several yards in thickness alternating with softer, thin-bedded sandstones.

20 7 ft. of chocolate slates exhibiting very fine laminations.

19 23 ft. of hard chocolate-coloured quartzite.

18 13 ft. of thin-bedded chocolate sandstone. These beds are crumpled in places.

17	78 ft.	of hard quartzite with "clots". Some current-bedding.
16	78 ft.	of reddish, thin-bedded, soft sandstone with "clots."
15	108 ft.	of very fine, even-grained, chocolate-coloured sandstone. Composed of angular quartz particles with some felspar grains and mica flakes.
14	252 ft.	of repeated alternation of bands of hard reddish quartzite and soft chocolate-coloured slates. Current-bedding and ripple-marks. In micro-slide the constituents are seen to be angular quartz grains, lots of muscovite, some felspar, and brown iron-stained material.
13	40 ft.	of hard quartzites.
12	27 ft.	of soft, laminated, very fine-grained, chocolate-coloured, somewhat argillaceous sandstone.
11	54 ft.	of very hard (strongly cemented) quartzite.
10	19 ft.	of red sandstone in part finely laminated. Dip, 65° to the west.
9	114 ft.	of hard, red sandstone.
8	81 ft.	of a crushed zone in soft, red sandstone.
7	11 ft.	of hard, red quartzite. Dip, 75° to the west.
	1,524 ft.	total thickness.

Passage Beds

6	22 ft.	of thinly laminated, sandy shale, somewhat calcareous; mainly chocolate-coloured.
5	202 ft.	of impure, calcareous beds, considerably crushed. Dip, 75° to the west.
4	31 ft.	of reddish-coloured, calcareous sandstone.
	255 ft.	total thickness.

Sub-Cambrian Limestones

3	222 ft.	of a flaggy series of impure limestones and calcareous slates, traversed by a fault line. Dip, 65° to the west.
2.	76 ft.	of impure flaggy limestones with a band of micro-cryptozoön limestone.
1	150 ft.	of impure flaggy limestones and calcareous slates. Faulting and crushing very obvious. In one belt, beds are reduced to a herring-bone crush. At the base of this block is a general shatter zone.
	448 ft.	total thickness.

Section across Sub-Cambrian Beds at Parachilna Gorge

Tuffaceous Series

1. An extensive series of chocolate shales, in which bedding planes are, for the most part, absent. The petrological character of this rock, as revealed in microscope slide, indicates a tuffaceous origin.

2 300 ft. of very fine-grained, chocolate-coloured, flaggy beds. Some bands harder than others. In thin section seen to be composed of minute angular grains of quartz and some felspar with a large proportion of detrital mica flakes. Chloritic and serpentinous material is present in notable proportion. This is obviously tuffaceous in origin. These beds are intersected by veins of baryta with some micaceous haematite.

300 ft. in partial thickness.

Arenaceous Series

3 720 ft. of flaggy greywackes, from grey to brown in colour. Dip, 50° to the west. In the hand specimen of some bands detrital particles of micaceous haematite are visible. In microscope section, the constituents are seen to be angular quartz grains, mica flakes and brown turbid products from the alteration of more basic particles.

4 42 ft. of laminated sandstones and some beds of massive quartzite. Current-bedding and ripple-marks. Some pseudo-fossil impressions of the clay gall type.

5 10 ft. of massive white quartzite forming the crest of the ridge. Dip, 65° to the west.

6 124 ft. of flaggy sandstones, mostly light brown in colour.

896 f . total thickness.

Tuffaceous Series

7 912 ft. of massive, chocolate-coloured beds. Dip, 45° to the west. Bedding planes not obvious in hand-specimen, but in microscope slide a sedimentary lamintion is revealed. It is clay-shale-like in fineness of grain. A great abundance of detrital mica flakes are revealed in the slide. These beds have every appearance of being tuffaceous origin. Copper-stained outcrops which have been opened up by prospectors were observed in this section.

8 138 ft. of fissile chocolate shale, alternating with harder bands. Under the microscope the harder bands are seen to be coarser-grained, but otherwise similar to the softer strata. Abundance of mica fragments present.

9. 237 ft. of thinly laminated beds of very fine silty material. This rock is certainly tuffaceous.

1,287 ft. total thickness.

Flaggy Shales, in Part Calcareous

10 57 ft. of faintly laminated and in places current-bedded, chocolate-coloured, somewhat calcareous shales. Dip, 45° to the west. A baryta vein crosses these beds.

11	70 ft.	of flaggy, calcareous beds showing changes from a chocolate colour to grey.
12	310 ft.	of laminated, hard, flaggy shales.
13	144 ft.	of thin-banded, flaggy shales only slightly calcareous. These beds are somewhat wavy and buckled.
14	50 ft.	of somewhat calcareous, thin flaggy shales. Dip, 45° to the west.
	631 ft.	total thickness.

Calcareous Series

15	114 ft.	of flaggy shales, with occasional calcareous bands.
16	125 ft.	of calcareous, flaggy beds with vague markings.
17	296 ft.	of limestones with micro-cryptozoön structure. Dip, 45° to the west.
18	106 ft.	of calcareous beds, buff-coloured above.
	641 ft.	total thickness.

Passage Beds

19	54 ft.	of somewhat calcareous, hard, chocolate-coloured, silty shales. Fine laminations are a feature of portion of this section.
	54 ft.	total thickness.

Basal Cambrian Quartzite

20	396 ft.	of quartzite. Dip, 45° to the west.
21	1,120 ft.	of quartzite seen to extend west to and beyond a crest line some 500 yards further in that direction.
	1,516 ft.	in partial thickness.

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STRONGYLE NEMATODES FROM CENTRAL AUSTRALIAN KANGAROOS AND WALLABIES

By T. HARVEY JOHNSTON and P. M. MAWSON, University of Adelaide

Summary

The senior author took the opportunity, whilst accompanying anthropological expeditions to Central Australia between 1928 and 1936, to examine for the presence of parasites many of the larger marsupials shot in order to supply meat for the aborigines assembled at the various camping places. Generally, only the stomach was searched because of the lack of time and the prevalence of very persistent muscid flies. In those cases where the intestine was examined, nematodes were not found in it. This accounts for the absence of trichostrongyles amongst the material studied. In spite of the long periods of dry weather and the low rainfall of the regions visited, the very heavy infestation of nearly all stomachs examined was remarkable. No doubt the scanty soil in the vicinity of the few springs and rockholes becomes heavily contaminated with eggs and larvae. The great number of different species and of individual worms to be found reminds one of similar conditions often encountered in the digestive tract of other herbivores such as the horse, ox, sheep, elephant, etc.

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[Read 11 August 1938]

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The two main animals searched were the rock wallaby, *Petrogale lateralis* Gould, which has a wide distribution in Central Australia and adjacent parts of South Australia, though restricted to the very rocky areas; and the euro, *Macropus robustus* Gould, occupying the less rocky parts of the hilly country in the same regions. The local subspecies was *M. r. erubescens* Sclater. Occasionally a kangaroo, *Macropus rufus,* Desm., was taken on the great plains. We have included in our examination some material from *M. isabellinus* Gould, a species (or perhaps a subspecies of *M. robustus)* inhabiting a part of North-western Australia, the actual host specimens having died in Sydney Zoological Gardens, the material having been received through the kindness of the Director, Mr. A. S. Le Souef.

The localities mentioned in this paper are Mount Liebig, now included in the northern portion of the Aboriginal Reserve in Central Australia; Cockatoo Creek, lying further to the northward; Hermannsburg, in the Macdonnell Ranges; also the following localities in northern South Australia: Ernabella in the Musgrave Ranges, and Nepabunna in the northern Flinders Ranges. The types of all new species described in this paper have been deposited in the South Australian Museum.

Hosts and Parasites Referred to in this Account

Macropus robustus erubescens Sclater.

Labiostrongylus macropodis; L. longispicularis Wood; *L. grandis.*

Cloacina minor; C. parva; C. communis; C. frequens; C. macropodis; C. dubia; C. australis; C. magna; C. curta.

Macropus isabellinus Gould.

Labiostrongylus longispicularis Wood.

Macropus rufus Desmarest.

Labiostrongylus longispicularis Wood.

Cloacina minor; C. petrogale; C. hydriformis; C. liebigi; C. inflata.

Petrogale lateralis Gould.

Pharyngostrongylus alpha; P. beta.

Labiostrongylus longispicularis Wood; *L. petrogale.*

Cloacina minor; C. parva; C. macropodis; C. petrogale; C. hydriformis; C. ernabella; C. elegans.

Unless otherwise indicated, all species of nematodes mentioned above are considered new. The absence of species of *Macropostrongylus* and the abundance of species and individuals of the related genus *Cloacina* are noteworthy. *Pharyngostrongylus* was found only in rock wallabies *(Petrogale)*. *Labiostrongylus* was represented in all host species examined.

Of the species found in *Macropus robustus, Cloacina minor, C. parva* and *C. communis* were by far the most common; *C. frequens* and *C. macropodis* very common; *C. australis, C. magna* and *C. curta* not uncommon; *C. dubia* was recognised only once; and a few Labiostrongyles were found in nearly all examinations. Only one stomach from *Macropus rufus* from Central Australia was searched, most of the parasites being species of *Cloacina*, but worms obtained many years ago from a red kangaroo from the western plains of New South Wales were identified as *L. longispicularis*, as also were worms from *Macropus isabellinus* from North-western Australia.

The commonest parasites of the stomach of *Petrogale lateralis* were *Cloacina minor, C. parva, C. petrogale, C. hydriformis, Pharyngostrongylus alpha, P. beta,* and *Labiostrongylus petrogale. C. ernabella* was fairly common. The remainder were much less frequently met with.

All parasites described in this paper were collected from the stomach.

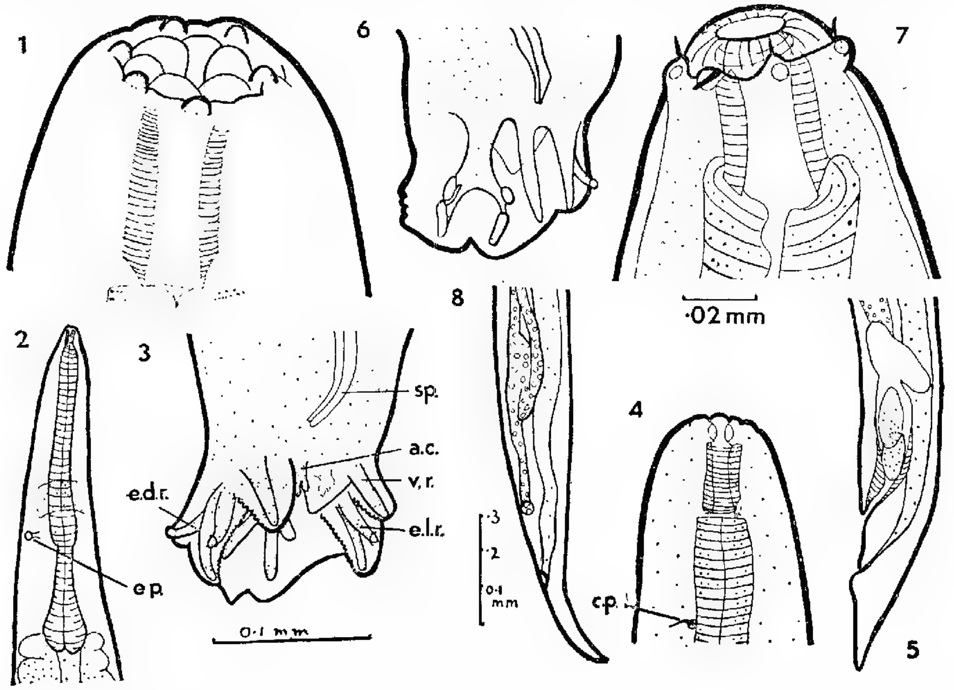
Pharyngostrongylus alpha n. sp.

Figs. 1-5

Host—Petrogale lateralis, Mount Liebig.

Short, thin, 6-7·5 mm. long in both sexes. Cuticle with very fine striations. Anterior end with six small rounded papillae, inwardly from these are six rounded inner lips surrounding narrow mouth, 5 μ diameter. A short passage, 7 μ long, with slightly chitinised walls, leads into a vestibule, 0·04 mm. long, 0·012 mm. wide, with strongly chitinised striated walls. Oesophagus differentiated as in succeeding species. Excretory pore behind nerve ring and lying at junction of the two oesophageal regions. Cervical papillae thread-like; about 0·12 mm. from anterior end. Anterior end of intestine with thick sacculate walls.

Male—Ventral lobes of bursa quite separated from each other and almost so from the long lateral lobes; dorsal lobe well defined with slight median cleft. Inside wall of bursa with small rough papillae of various sizes, very small on dorsal and ventral lobes, largest near bursal edge, most abundant on lateral lobes. Ventral rays close together, parallel, passing into apex of ventral lobes; externo-lateral short like externo-dorsal, both forming projections on lateral wall of bursa; lateral rays run together to bursal edge in longest part of lobe; externo-dorsal arises separately; dorsal ray bifurcates just beyond half its length, each part giving rise to a short lateral branch, none of these branches reaching bursal edge. Genital cone, small, rounded; accessory cone with two finger-like processes on each side; spicules 1·36 mm. long, straight, with striated alae extending for



References to lettering—a.c., accessory genital cone; b.p., prebursal papilla; b.r., chitinous ring in buccal capsule; c.p., cervical papilla; d.l., dorsal lip; d.r., dorsal ray; e.c., moulting cuticle; e.d.r., externo-dorsal ray; e.l.r., externo-lateral ray; e.p., excretory pore; g.c., genital cone; i., intestine; l.c., leaf crown; l.l., lateral lip; o., oesophagus; s.l., submedian lip; s.p., spicule; t.p., tail papilla; v.r., ventral ray.

Figs. 1-5. *Pharyngostrongylus alpha*—1, head, antero-lateral; 2, anterior end, lateral view; 3, bursa, ventro-lateral; 4, head, lateral; 5, female, posterior end. Figs. 6-8 *Pharyngostrongylus beta*—6, bursa, dorsal; 7, head, antero lateral; 8, female, posterior end. Figs. 1 and 7 to same scale; 6, 3 and 4; 2, 5 and 8.

almost their whole length, tips curved; gubernaculum heart-shaped when viewed dorsally.

Female—Uteri parallel, joining near vulva; vagina straight, rather short and, except in very young specimens, projects through vulva and sometimes is rolled back like a cuff. Anus 0·3 mm. and vulva 0·082 mm. from tip of thin tail.

This species differs from *P. beta* in the characters of the head, position of excretory pore, relative length of oesophagus and of spicules, and in total length of body. It resembles *P. australis* in many features, but differs in dimensions of vestibule and in possessing no leaf crown. Neither Wood nor Mönnig noted the presence of an accessory genital cone, and the continuation of the dorsal ray noted by them was not observed in the present species.

Pharyngostrongylus beta n. sp.

Figs. 6-8

Host—*Petrogale lateralis,* Mount Liebig.

Short, thin, more or less straight when preserved. Male, 3·9-5 mm.; female, 7-8 mm. long. Cuticle very finely striated. Mouth collar with six small papillae, each with an antero-lateral projecting portion, bearing a delicate process 7 μ long. Inwardly from the collar arises the smooth dome-like anterior extremity surrounding the circular mouth. No leaf crown. Buccal capsule 18 μ in diameter, 9 μ in length, with chitinous ring at its base. Vestibule about 0·04 mm. long in young specimens, with annulate chitinous wall. Oesophagus long, narrow, with longer anterior region and shorter narrower posterior portion widening into a bulb before joining intestine. Cervical papillae bristle-like, about 0·08 mm. (in young specimens) from anterior end. Excretory pore just anterior to junction of the two regions of oesophagus. Nerve-ring just in front of level of excretory pore.

Male—Inside of bursa with numerous, very small, papillae, fewer and smaller on dorsal lobe. All lobes separated by deep clefts; dorsal lobe with short median cleft. Externo-lateral and externo-dorsal rays give rise each to a lateral projection on bursa. Medio- and postero-laterals extend almost to edge of bursa. Dorsal ray bifurcates just beyond half its length, each part giving off a shorter lateral branch; no part of dorsal ray reaches edge of bursa. Genital cone short; accessory cone with two finger-like projections. Spicules straight, 1·4 mm. long, with striated alae and curved tips. Gubernaculum not seen.

Female—Uteri parallel; vagina straight; distance from vulva to anus about equal to that from anus to tip of tail. Body narrows from level of vulva to form a thin tail.

P. beta differs from all described species in the absence of a leaf crown and in the character of the head papillae. The anterior end suggests that of *P. australis* in general form, but the latter has a narrower vestibule and its anus and vulva are much nearer to each other. The oesophagus and dorsal ray of the bursa resemble those of *P. brevis,* but the new species differs from the latter in having longer spicules, papillae on the bursa and in the absence of a leaf crown.

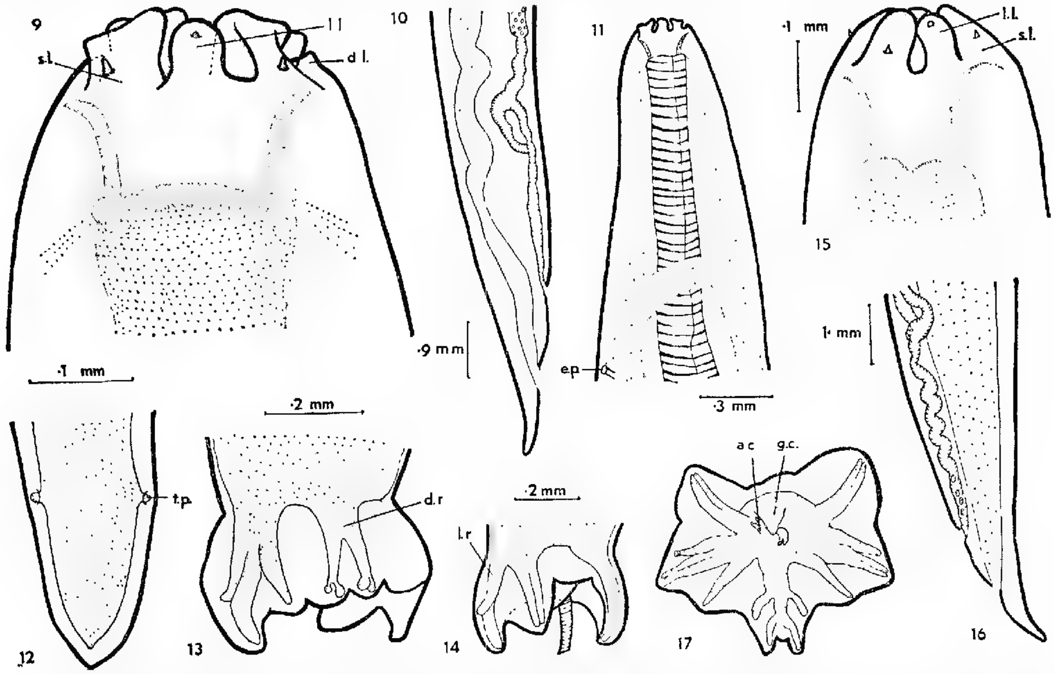
Labiostrongylus macropodis n. sp.

Figs. 9-14

Host—*Macropus robustus,* Mount Liebig, Cockatoo Creek.

Males, 21-30 mm. long; females, 24·8-31·2 mm. Maximum breadth, 1·1 mm. Long stout worms with anterior end prolonged into eight lip-like processes—four of them large bilobed submedian, two rather shorter simple lateral, one short simple dorsal, and one short simple ventral. Each submedian with long conical papilla, each lateral with small rounded papilla. Buccal capsule 0·08 mm. long, 0·15 mm. wide, lined by cuticle. Oesophagus long, about one-fifth body length, straight. Anterior end of intestine surrounded by granular mass forming two pairs of lateral lobes. Nerve-ring at about 1 mm. from anterior end, and just in front of excretory pore. Cervical papillae not observed.

Male—Spicules long thin striated, sometimes much curved, 9·4-11·1 mm. long, about 1-2·5 of body length. Bursa large, lobes well differentiated, ventral lobes separate. Ventral rays reach almost to bursal edge. Externo-lateral rays



Figs. 9-14. *Labiostrongylus macropodis*—9, female head; 10, female, posterior end; 11, anterior end, lateral; 12, female, tail; 13, bursa, lateral; 14, bursa, ventral. Figs. 15-17. *Labiostrongylus longispicularis*—15, head, male; 16, bursa, flattened, posterior view; 17, female, posterior end. Figs. 9 and 12 to same scale; 11 and 17.

short, close to medio-laterals; medio- and postero-laterals long, reaching almost to bursal edge; externo-dorsal arises from same root as laterals, is thick, intermediate in length between medio- and externo-laterals. Dorsal ray relatively narrow, dividing at about half length, each branch terminating in two short rounded processes reaching almost to bursal edge.

Female—Uteri parallel, uniting at some distance from vulva; ovejectors 0·8 mm. long; vagina 3 mm., narrow. Anus about midway (0·94 mm.) between vulva and tip of tail. Tail long, narrow, tapering, with rounded extremity.

The species differs from *L. labiostrongylus* and *L. longispicularis* in dimensions, structure of the dorsal ray, and length of spicules.

Labiostrongylus longispicularis Wood 1929

Figs. 15-17

Wood's unfigured account was based on a male specimen from *Macropus robustus* var. *woodwardi,* a race living in the Murchison district of Western Australia. Our material was taken from *M. robustus* var. *erubescens,* from Nepabunna, Northern Flinders Ranges, South Australia.

Long stout worms; male, 4·4 cm.; female, 5·6 cm.; slightly tapering anteriorly. Six lips, four submedian, two lateral, submedian lips broadened, slightly bifurcated at tips and bending inwards over mouth; each submedian with short bristle just behind its midregion; each lateral with small rounded papilla near tip; no leaf crown. Buccal capsule 0·115 mm. long in male, slightly longer than broad, walls thinly chitinised, cavity as wide anteriorly as posteriorly. Oesophagus 8·7 mm. long in male, 9 mm. in female (1:5 and 1:6·2 of body length respectively), narrow, without definite bulb, though wider near base than anteriorly. Nerve cord about 1·6 mm. from anterior end; excretory pore about 2 mm. from head end. Cervical papillae not observed.

Male—Bursa stout, lobes definite, ventral lobes distinct from laterals and separated from each other ventrally. Ventral rays parallel, arising near laterals but soon bending ventrally to the corner of corresponding ventral lobe. Ventro-lateral ray short, bending outwards to form slight projection (5 μ) on side of bursa. Medio- and postero-laterals much longer, travel together, the corresponding part of the lateral lobe forming a horn-like projection when seen dorsally or ventrally. Externo-dorsal ray short, arises with laterals, and projects like the ventro-lateral. Dorsal lobe separated from lateral by deep fissure. Dorsal ray very stout, giving off a lateral branch on each side midway from its origin, the branch extending almost to bursal edge at lateral termination of dorsal lobe; main ray divides into two parallel branches. Dorsal lobe long, its posterior edge forming two or three lappets, the two outer (which contain the ends of the dorsal ray) rounded; between these may be a third more or less developed, sometimes containing an abortive median continuation of dorsal ray. Genital cone short, conical with small button-like papilla at tip. Accessory cone wider, not quite so long, with several elongate processes laterally. Spicules 17·8 mm. long (1:2·5 of body length), stout, fairly straight, striated, with striated alae.

Female—Uteri joint about 3·8 mm. from vulva; vagina narrow, coiled; anus 1·4 mm. from tip of short narrow pointed tail; vulva 2·5 mm. from tip of tail.

A male *Labiostrongylus* was found in the stomach of a rock wallaby, *Petrogale lateralis,* from Mount Liebig, Central Australia, agreeing in its head characters with *L. longispicularis.* The position of the nerve cord was similar, but the excretory pore was posterior to the oesophagus instead of being near the nerve-ring, the oesophagus was about one-seventh of the body length, and the spicules 1:5·6 of body length instead of 1:2·5. The specimen was only 24 mm. long. The bursa was asymmetrical and the dorsal ray differed somewhat from that described above.

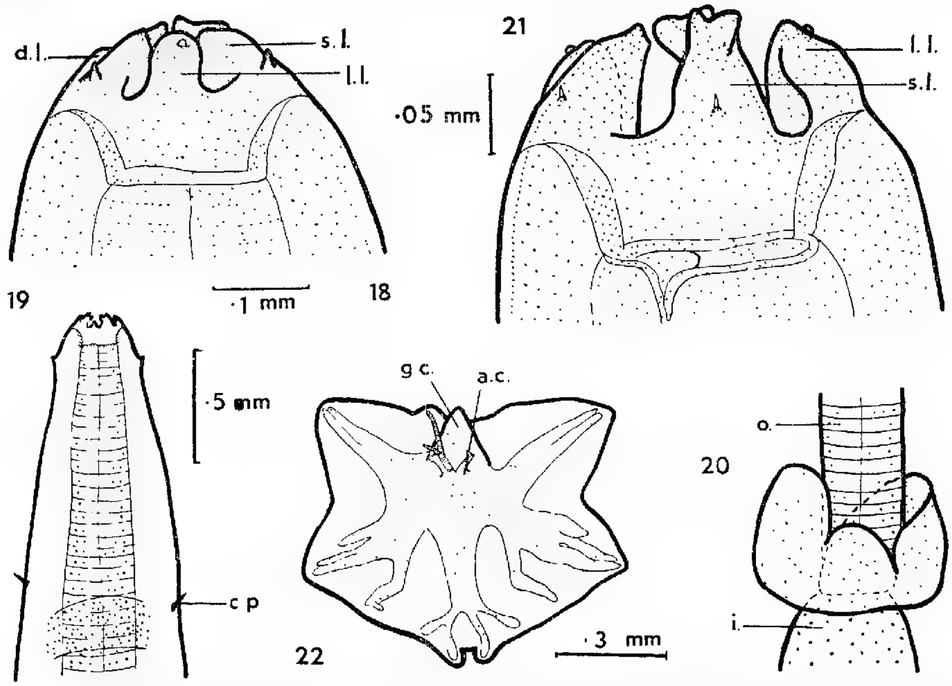
As there was only one specimen available, we deem it unwise to erect a new species for it. It seems to be most closely related to *L. longispicularis.*

A number of specimens taken from *Macropus rufus* from western New South Wales and from *M. isabellinus* (which is probably a variety of *M. robustus)* from North-western Australia (from Sydney Zoological Gardens) also belong to *L. longispicularis.*

Labiostrongylus grandis n. sp.

Figs. 18-20

From *Macropus robustus,* Mount Liebig. Male, 4 to 4·5 cm.; female, 6·8 to 7·5 cm. Very large worms, resembling *L. longispicularis* in general proportions. Maximum diameter of female, 2·5 mm. Anterior end with eight prolongations characteristic of genus; submedian bilobed; lateral lips larger than dorsal and



Figs. 18 20. *Labiostrongylus grandis* 18, male head, lateral; 19, anterior end, male, ventral; 20, junction of oesophagus and intestine. Figs. 21-22. *Labiostrongylus petrogale*—21, head, young female, submedian view; 22, bursa, flattened, posterior view.

ventral, shorter than submedians. Laterals, ventral and dorsal lips simple, conical. Submedian and lateral lips each with papilla, conical on submedians, small and rounded on laterals. Apparently small rounded papillae about 0·2 mm. from anterior end, two of them lateral and perhaps one ventral and one dorsal. Cervical papillae long, thread-like, arising from cuticular depression 1·1 mm. from anterior end. Buccal capsule shallow, 0·12 mm. wide, with chitinised portion 0·08 mm. long; from tip of lips to floor of capsule 0·15 mm. Nerve-ring 1·3 mm. and excretory pore 1·8 mm. from anterior end. Oesophagus long, straight, 0·8-0·9 mm. (one-fifth body length) in male, one-sixth in case of female.

Male—Bursa with well-defined dorsal, lateral and ventral lobes; ventrals quite separated from each other and smaller than laterals. Ventral rays equal, parallel. Externo-laterals, laterals and externo-dorsals arise from same root, the first shortest, the other two reaching nearly to bursal edge. In posterior view of bursa externo-lateral and externo-dorsal rays appear to form projections on lateral walls. Dorsal ray stout, bifurcating at beginning of second half of its length, each branch subdividing at half its length into an inner club-shaped and an outer short ray, neither reaching bursal edge. Spicules 12·4 mm. long, 1 : 3·3 of body length, fairly straight, striated, with alae extending nearly to the rounded tips. Accessory genital cone not observed.

Female—Body narrows suddenly after vulva; tail long, thin, with rounded end bearing two small lateral subterminal papillae, 0·2 mm. from tip. Vulva 2·6 mm. from posterior end. Uteri wide but narrowing greatly into ovejectors just before the two join about 4 mm. from vulva; vagina narrow, twisted. Eggs, 0·145 by 0·11 mm.

The species differs from *L. labiostrongylus* in its spicules; from *L longispicularis* in its lips; and from other species in the structure of the dorsal ray.

Labiostrongylus petrogale n. sp.

Figs. 21-22

From *Petrogale lateralis*, Mount Liebig. Male up to 4·4 cm., female up to 6 cm. Four submedian lip-like prolongations bilobed at distal end, almost meeting over buccal capsule. Lateral lips shorter, conical, with small rounded papilla near tip; submedian lips each with thin pointed papilla arising from slight bulbous cuticular enlargement. No dorsal or ventral lips. Buccal capsule with thick chitinous lining (0·11 mm. long) continuous at its base with lining of oesophagus; floor of capsule 0·195 mm. from anterior end of lips. Oesophagus 6·66 mm. long in male, *i.e.*, one-sixth body length, narrow, surrounded by mass of dark cells at junction with intestine. Cervical papillae thin, about midway between nerve-ring and anterior end. Nerve-ring and excretory pore at about level of end of first quarter of oesophagus.

Male—Bursa large; ventral lobes separated from each other, distinctly marked off from laterals; dorsal lobe with short median cleft. Ventral rays long, parallel, reaching bursal edge. Externo-lateral shorter than laterals, which extend almost to edge and are cleft for nearly half length; externo-dorsal thick, arises with laterals, and longer than externo-laterals. Dorsal ray very thick, bifurcating at two-thirds length, each branch giving off a lateral, all final branches slightly bulbous and extending almost to bursal edge. Genital cone long, conical; accessory cone with two short thick processes, each ending in one or two finger-like projections. Spicules about 7·25 mm., *i.e.*, one-fourth to one-sixth body length, curved, with striated alae along most of length. Gubernaculum present.

Female—About 0·2 mm. in maximum diameter. Anus about midway between vulva and tip of tail; latter rather short, tapering, with rounded end terminating in button-like structure. Vagina long, narrow, twisted.

The species resembles *L. longispicularis* in its head region, but differs in the length of spicules and the character of the dorsal ray.

CLOACINA Linstow (emend.)

Linstow's original diagnosis (1898, 287) indicated that the genus differed from all known nematode genera in having the vulva and anus united into a female cloaca. Railliet and Henry (Bull. Soc. Path. exot., 6, 1913, 506) stated that the two apertures were distinct and that the genus was synonymous with *Zoniolaimus*. York and Maplestone (1926) gave a much more satisfactory diagnosis based on Linstow's account and figures of the type *C. dahli*, as also did Baylis and Daubney (1926). The original material came from *Macropus browni* Ramsay, from Ralum, New Britain. The genus has been placed in Strongylidae; Cloacininae; Cloacinidae; Trichoneminae; and amongst the Strongyloidea "insufficiently known."

Amongst our material from Australian marsupials we have found numerous species which we have been able to assign to Linstow's genus as amended by us. A revised diagnosis is now given.

Trichoneminae—Mouth directed straight forwards. Mouth collar with 6-8 lips, four of them submedian and two lateral, with in some cases a dorsal and a ventral; each submedian lip with a prominent papilla; on lateral lips usually an insignificant papilla. Buccal capsule cylindrical, broader than long; leaf crown of six elements arising from its internal surface and projecting through mouth opening. Oesophagus with more or less developed swelling at its posterior end.

Male—Well developed bursa; ventral lobes joined in front; ventral rays cleft distally; externo-dorsal may or may not arise with laterals; medio- and postero-laterals lying side by side; dorsal ray bifurcates after an half to one-third of its length, and the two branches subdivide further back. Spicules usually long, thin, with striated alae. Gubernaculum present or absent.

Female—Body tapering behind vulva; tail usually pointed; distance between vulva and anus usually about equal to that between anus and tip of tail. Uteri parallel.

Parasites of the stomach of marsupials. Type *C. dahli* Linstow.

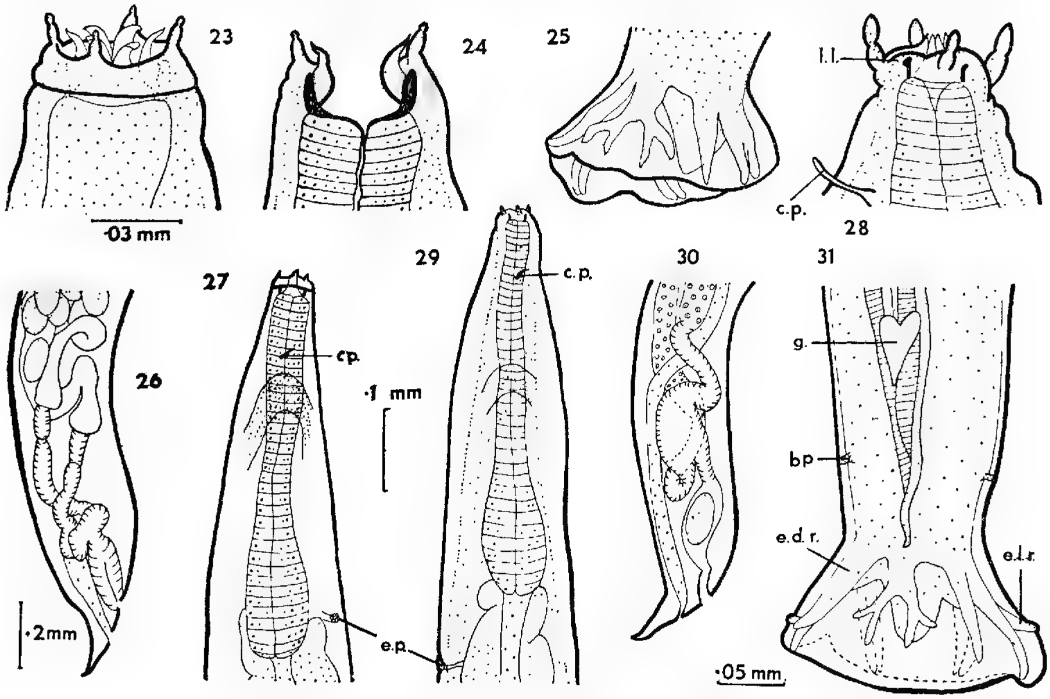
The chief distinctions between this genus and *Macropostrongylus* are the presence of lips and the relative sizes of the lateral and submedian papillae.

Cloacina elegans n. sp.

Figs. 23-27

From *Petrogale lateralis*, Hermannsburg. Male 6·2 mm. long, 0·5 mm. maximum breadth; female 6-11 mm. long, 0·6 mm. maximum breadth; rather thick body forming at least one coil. Six very low lips; the two laterals each with minute rounded papilla; four submedians each with conical papilla consisting of longer proximal and small button-like distal portion. Buccal capsule with stout chitinous ring, 0·014 mm. long, 0·025 mm. diameter, continuous with chitinous floor; six elements of leaf crown arise from base, extend inwardly and then forwards to surround mouth aperture, free end of elements projecting beyond lips. Cervical papillae thread-like, about 0·1 mm. from head end; nerve-ring at 0·17 mm., and excretory pore at 0·37 mm. from anterior end in female. Oesophagus short, 0·52 mm. long, straight, anterior part slightly wider and extending beyond nerve-ring, bulb in region of excretory pore. Anterior end of intestine thickened, without lobes.

Male—Spicules 2·2 mm., 1:3 of body length, not straight, with narrow striated alae extending along almost whole length, tips rounded. Gubernaculum heart-shaped in dorsal view. Bursa large, lobes distinct, laterals longest. Ventral



Figs. 23-27. *Cloacina elegans*—23, female head; 24, female head, optical section; 25, bursa, dorso-lateral; 26, female, posterior end; 27, head end, female, lateral; Figs. 28-31. *Cloacina hydriformis*—28, head, female; 29, anterior end, male, lateral; 30, female, posterior end; 31, male, posterior end, dorsal Figs. 23, 24 and 28 to same scale; 25 and 31; 26 and 30; 27 and 29.

rays thin, straight, almost reaching bursal edge; externo-lateral and externo-dorsal project slightly on lateral wall of bursa; laterals long, slender, almost reaching edge. Dorsal ray stout, soon dividing, each branch passing postero-laterally and then giving off a lateral ray extending outwards, then bending to run parallel with main branch; none of the dorsal branches reaching bursal edge. Genital cone fairly large; dorsal lip of cloaca without processes.

Female—Body narrows suddenly in region of vagina; tail thin, pointed, bending dorsally. Uteri parallel; ovejectors 0·49 mm. long; vagina 2·6 mm. long, straight; vulva about 1·3 mm. in front of anus; anus about 1·3 mm. from tip of tail. Eggs 0·035 by 0·16 mm.

Cloacina hydriformis n. sp.

Figs. 28-31

From *Petrogale lateralis,* Mount Liebig; Hermannsburg; Ernabella.

Short; males, 4·4-5·1 mm. long, 0·29 mm. broad; females, 5·8-6·5 mm. long, 0·36-·45 mm. broad. Four submedian lips each with long "two-jointed" papilla, projecting characteristically from head; two lateral lips. Buccal ring long, thin, with upper edge turned outwards; elements of leaf crown relatively thick, arising from base of capsule, with free ends bending inwards around mouth opening. Cuticle inflated in oesophageal region. Oesophagus 0·26-0·4 mm. long, 1 : 12-17 of body length, narrow, straight, with slight enlargement. Cervical papillae bristle-like, 0·08 mm. from head end. Nerve ring at mid-oesophagus, about 0·2 mm. from anterior end. Excretory pore at posterior end of oesophagus, 0·45-·49 mm. from head end.

Male—Spicules stout, short, 1·14-1·4 mm., 1 : 3·6-3·8 of body length, with alae on second half of length and ending near tips, tips curved slightly. Gubernaculum more or less heart-shaped in dorsal or ventral view, larger (thicker) at anterior than at posterior end when viewed laterally. Small prebursal papillae at about 0·25 mm. in front of anterior edge of bursa. Bursa lobes hardly distinct, ventral lobes joined. Ventral rays long, thin, reaching bursal edge; externo-laterals short, projecting on side of bursa; laterals reaching bursal edge; externo-dorsals short, equal to externo-laterals; dorsal ray very short, bifurcating after half length, each branch giving off rather short lateral stem. Genital cone long, rounded.

Female—Uteri parallel; ovejectors 0·4 mm. long; vagina short, straight; vulva 0·3-·36 mm. from posterior end. Tail narrows sharply beyond vulva and is bent back to make angle with body. Anus at 0·2 mm. from tip of tail. Eggs, 0·17 by 0·08 mm.

Specimens also assigned to this species were taken from the stomach of *Macropus rufus* from Mount Liebig. They agreed in all particulars except in having relatively shorter spicules which were only one-fifth body length.

Cloacina frequens n. sp.

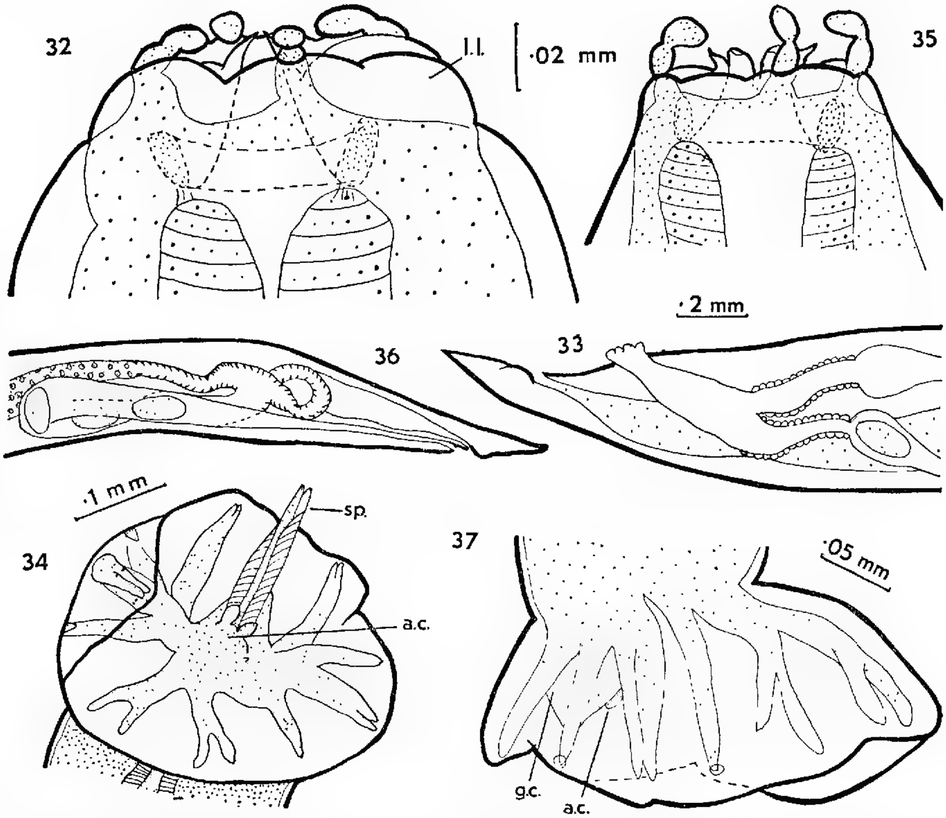
Figs. 32-34

From *Macropus robustus,* Mount Liebig; Cockatoo Creek.

Male, 6-11·5 mm. long, 0·4 mm. broad; female, 14·7-18 mm. long, 0·72 mm. broad. More or less straight, tapering towards ends. Six lips; four submedian each with a "two-jointed" papilla bent inwards over mouth in most specimens; lateral lips with very small papilla. Cuticle ridged behind anterior end. Buccal capsule with chitinous ring from which arises leaf crown of six elements; ring wider at top (0·055 mm.) than at base (0·045 mm), and 0·013 mm. deep. Oesophagus commences at about 0·05 mm. from anterior end of lips, 0·9-1·13 mm.

long in male (1:7-10 of body length), 1·03-1·27 mm. long in female (1:13-17 of body length); almost straight, narrow except for slight enlargement near posterior end. Nerve ring at second quarter of oesophagus length and 0·3-0·43 mm. from anterior end. Excretory pore in region of third quarter of oesophagus and 0·55-0·8 mm. from anterior end, distance varying with length of worm. Cervical papillae long, thread-like, about one-eleventh body length from anterior end in male, and one-twentieth in female.

Male—Ventral lobes of bursa joined. Ventral ray long, thin; externo-lateral short; medio- and postero-laterals joined except at tips, latter ray slightly longer,



Figs. 32-34. *Cloacina frequens*—32, head, female; 33, female, posterior end; 34, bursa, flattened, posterior view. Figs. 35-37. *Cloacina australis*—35, head, female; 36, female, posterior end; 37, bursa, dorso-lateral. Figs. 32 and 35 to same scale; 33 and 36.

both extending almost to bursal edge; externo-dorsal short, stout, arising from same root as laterals; dorsal ray dividing into two, each branch bifurcating near distal end, no branch reaching edge. In many specimens each of the first two branches of the dorsal ray gives off a short narrow stem laterally, just before bifurcation. Spicules short, 0·86-·89 mm., 1:7-13 of body length, tapering to tips, alae extending nearly to tips. Gubernaculum small, irregular; genital cone long; pair of accessory processes present.

Female—Uteri parallel; ovejectors 0·32 mm. long, uniting near vulva; vagina very short, 0·4 mm.; vulva 0·22 mm. in front of anus. Tail more or less straight, body tapering rapidly to vulva and ending in sharp point. Anus at about 0.27 mm. from tip. Eggs, 0·17 by 0·08 mm.

Cloacina australis n. sp.

Figs. 35-37

From *Macropus robustus,* Mount Liebig; Cockatoo Creek.

Body rather long, curved, tapering towards anterior end; 10 mm. long, 0·5 mm. broad in male; 9·5-11·5 mm. long, 0·6 mm. broad in female. Cuticle in vicinity of level of anterior end of oesophagus standing out from underlying tissue, and though seen in all specimens the condition may be an artefact as it was more marked in some than in others. Head with 4 shallow wide submedian lips; perhaps a pair of narrower lateral lips between them; submedians each with large "two-jointed" papilla. Buccal capsule with chitinous ring 0·017 mm. long, 0·04 mm. diameter (in female); distance from floor of cavity to tip of lips 0·02 mm. Leaf crown of six elements arising from lower inner edge of ring and projecting inwards; outer edge of each element appearing to be continuous with corresponding lip; free end of each element bent backwards. Nerve ring around oesophageal bulb and 0·32-0·4 mm. from anterior end. Cervical papillae long, hair-like, 0·39 mm. from head end, each arising from button-like outgrowth. Oesophagus 0·64-·75 mm. long, narrow, straight in anterior half, then bulbous, followed by a constriction and then by a club-shaped end leading into the narrow intestine whose anterior end surrounds the end of the oesophagus; oesophagus 1 : 14-16 of body length.

Male—Lateral lobes of bursa distinctly separated from dorsal and ventral lobes; ventrals joined to, but distinct from, each other; dorsal lobe with median cleft. Ventral rays long, reaching bursal edge; laterals long, not reaching edge; externo-lateral and externo-dorsal project on side of bursa; externo-dorsal arising separately. Dorsal ray subdivides near its base, each branch soon dividing into inner long thin branch and a lateral short thicker branch, neither reaching edge. Spicules long 4·4-4·8 mm. 1 : 2·1-2·3 of body length, narrow, with striated alae, fairly straight. Genital cone well developed, conical; dorsally to it are two small projections which may be associated with an accessory genital cone.

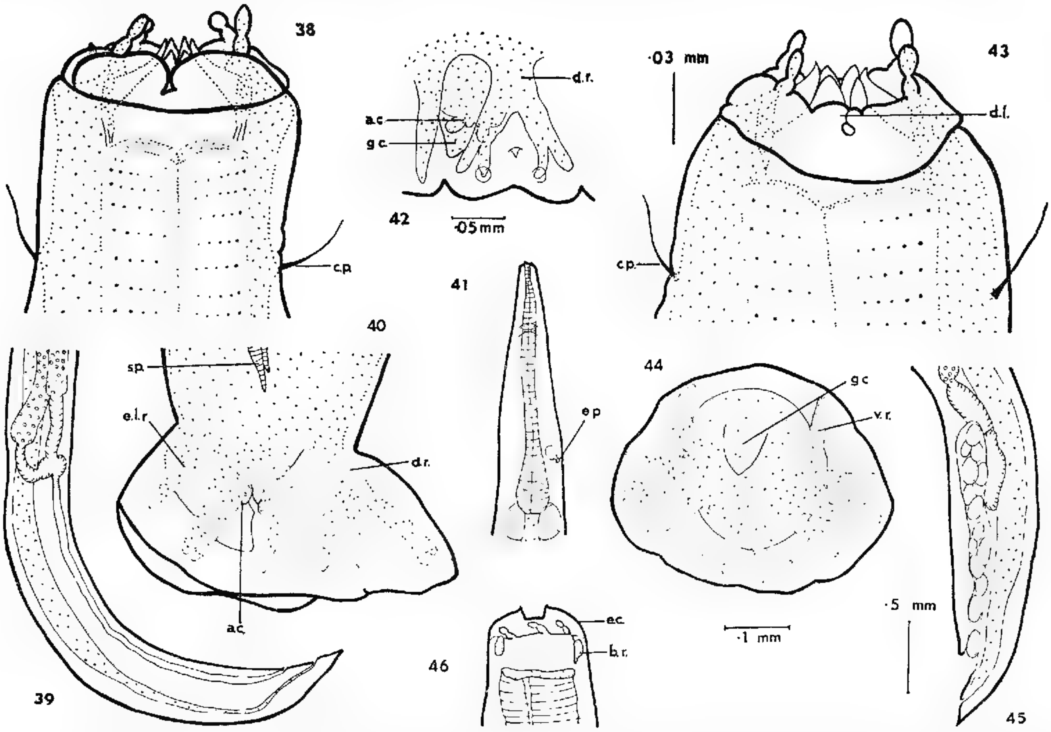
Female—Uteri long, parallel, uniting about 0·8 mm. from posterior end of body; vagina passing forwards, then turning back to vulva lying 0·3-0·4 mm. from tip of tail. Tail straight, tapering; tip directed backwards. Anus 0·2 mm; from tip.

Cloacina communis n. sp.

Figs. 38-41

From *Macropus robustus,* Mount Liebig; Cockatoo Creek.

Male, 11 to 13 mm. long; female, 15-45 mm., generally 20-25 mm. long, stouter towards anterior end, tapering markedly in posterior third, with slight prominence in region of vulva. Anterior end suddenly narrowed in buccal region. Six lips, four submedians each bearing elongate papilla with marked constriction, two laterals each with small conical papilla. Nerve ring 0·32-0·42 mm., excretory pore 1·2-1·4 mm., and cervical papillae 0·09-0·11 mm., from anterior end. Maximum breadth 0·55-·63 mm. in male, 0·6-·7 in female. Buccal ring longer and wider than in most species of the genus; chitinous ring thin, 0·04 mm. diameter, 0·021 mm. long in male; leaf crown of six elements arising about half-way along ring. Oesophagus 1·25 to 1·77 mm. long, 0·07 mm. wide, length 1:7·5-13 of body length, usually 1:8-9; first and second thirds slightly wider than last third which ends in a spherical bulb 0·22 mm. in diameter. Anterior end of intestine surrounded by mass of granular tissue arranged in paired lobes.



Figs 38-41. *Cloacina communis* 38, head, female, ventral; 39, female, posterior end; 40, bursa, dorso-lateral; 41, female, anterior end. Figs. 42-46. *Cloacina petrogale* —42, dorsal ray of bursa, genital cone, accessory cone; 43, head, female, ventral; 44, bursa, flattened, posterior view; 45, female, posterior end; 46, young female undergoing ecdytis. Figs. 39, 41 and 45 to same scale; 42, 40 and 46; 38 and 43.

Male—Spicules 3·47-4·13 mm. long, 1:2·7-3·7 of body length, slender, with striated alae. Gubernaculum appearing in dorsal view as heart-shaped structure between spicules. Genital cone short, directed dorsally; rudimentary accessory cone formed of two button-like processes on dorsal lip of cloaca. Ventral lobes of bursa not clearly marked off from each other or from lateral lobes. Ventral rays long, reaching almost to bursal edge, cleft at tip. Externo-lateral short, thick; medio- and postero-laterals together, longer than externo-lateral, but not reaching bursal edge; externo-dorsal thick, from same root as laterals, but shorter. Dorsal ray bifurcating after half its length, each branch subdividing into two equal rays after half its length, none reaching edge of bursa.

Female—Body narrowing rapidly beyond vulva; tail conical, short, pointed. Intestine narrowed before reaching anus, latter 0·2 mm. from tip of tail. Uteri parallel, joining some distance before vulva; vagina long, narrow, nearly straight; vulva 0·15 mm. in front of anus. Ripe eggs, 0·17 by 0·08 mm.

Cloacina magna n. sp.

From *Macropus robustus*, Cockatoo Creek.

Male 10 mm., fairly stout; female 30 mm., anterior region stout, posterior much thinner and curved. Anterior end with six low lips; four of them submedian, each with large papilla constricted into two parts; two laterals each with or without very small papilla. Buccal capsule very wide, with chitinous ring 0·07 mm. diameter, 0·02 mm. long, bearing leaf crown passing anteriorly and bending inwards. Oesophagus long, narrow, 1·4 mm. in male (1:7 of body length), 2·02 mm. in female (1:15); anterior two-thirds wider, 0·08 mm. broad in male at anterior end, 0·15 mm. wide at base where it widens into a bulb. Excretory pore at 0·9 mm. from anterior end, and just in front of oesophageal bulb; nerve ring at 0·26-·28 mm. from head end.

Male—Bursa rather longer than usual, with ventral lobe distinct from laterals but not deeply separated from them. Ventral rays long, narrow, parallel not separated, reaching almost to bursal edge. Externo-dorsal arising from same root as laterals and of same length, none of these reaching bursal edge. Medio- and postero-laterals separated for about half length. Dorsal ray divides after one-third length, each branch dividing into an inner and a rather shorter lateral, neither reaching bursal edge. Genital cone short, conical. Spicules 3·7 mm., 1:2·8 of body length, fairly straight, with wide striated alae ending near tips.

Female—Sudden narrowing beyond vulva; tail short, pointed, and strongly curved. Anus 0·2 mm., and vulva 0·25 mm. in front of tip of tail. Vagina rather long, about 2·1 mm., ovejectors directed forwards, 0·55 mm. long, leading into parallel uteri. Eggs, 0·17 by 0·08 mm.

The species closely resembles *Cloacina communis* but differs in size, positions of nerve ring and excretory pore, relative sizes of spicules and oesophagus, and form of the anterior end.

Cloacina petrogale n. sp.

Figs. 42-46

From *Petrogale lateralis*, Mount Liebig; Hermannsburg; Ernabella.

Male 7·5-8 mm. long, 0·48 mm. broad; female 10-21 mm. long, 0·75 mm. broad; body tapering more markedly anteriorly in both sexes. Eight lips arise inside mouth collar, each of the four submedians with long "two-jointed" papilla, dorsal and ventral lips represented by very shallow bilobed folds. Buccal capsule surrounded by chitinous ring, 0·031 mm. long, 0·6 mm. diameter (in female) and not reaching oesophagus; floor of capsule with thin chitinous plate. Leaf crown of six elements arising from about half-way up chitinous ring and bending inwards over mouth aperture and recurved at anterior edges. Cervical papillae 0·08 mm. from anterior end in female. Nerve ring at 0·24 (male), -0·4 mm. (female) from anterior end; excretory pore near oesophageal bulb, 1·14 mm. from head end in male. Oesophagus 1·06-1·4 mm. long in male, 1:6-7 of body length; 1·65-1·7 in female, 1:6 of body length in young specimens, 1:12·5 in large females; long, thin, with bulb at posterior end. Anterior end of intestine with distinct lobes.

Male—Bursal lobes not deeply separated from each other; two ventral lobes united. Ventral rays long, cleft for almost half length, reaching nearly to bursal edge. Externo-ventral, ventrals and externo-dorsals arising from same root; first longest and almost reaching edge; ventrals long, stout, not reaching edge; externo-dorsal almost as long as externo-ventral. Dorsal ray divides after half its length, each branch bifurcating into more or less equal rays, none reaching bursal edge. Spicules 3·3-3·88 mm., 1:2-2·4 of body length, with alae striated almost to tips, curved in body. No gubernaculum.

Female—Tail short, conical; vagina long, almost straight; uteri parallel; ovejectors about 0·45 mm. Anus at 0·3 mm. and vulva at 0·5 mm. from posterior end in large females. Eggs, 0·19 mm. by 0·08 mm.

Cloacina macropodis n. sp.

Figs. 47-50

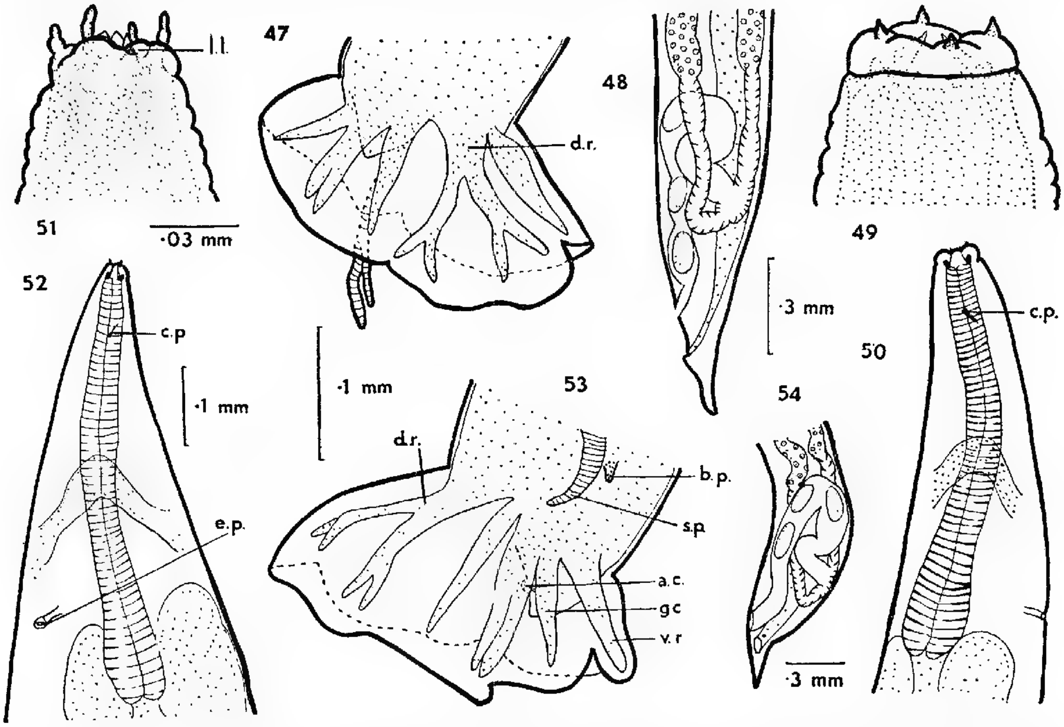
From *Macropus robustus* and *Petrogale lateralis,* Mount Liebig; Cockatoo Creek.

Rather short slender worms tapering at each end. Male 7-7·55 mm. long, 0·28 mm. maximum breadth; female 8·2-10·6 mm. long, 0·38 mm. maximum breadth. Two lateral lips; four submedian lips each with small conical papilla of two parts, larger basal portion and smaller conical tip. Buccal capsule broader than long, with chitinised ring around base, 0·01 mm. long, 0·026 mm. diameter at bottom, wider in anterior part. Leaf crown of six elements apparently. Nerve ring around middle of oesophagus, at 0·23 mm. in male and 0·24-0·35 mm. in female from anterior end. Excretory pore just in front of posterior end of oesophagus and about 0·43 mm. from head end in female. Cervical papillae thread-like, at 0·065 mm. from anterior end in female. Oesophagus 0·4-·54 in male (1:14-19 of body length), 0·49-·58 in female (1:17-18 of body length), narrow, widening at posterior end.

Male—Lobes of bursa not separated by deep clefts; bursa longer dorsally than ventrally. Ventral rays long, slender, almost reaching bursal edge; externo-lateral shorter, stouter; medio- and postero-laterals separated near tips, latter ray slightly longer; externo-dorsal arising apart from laterals, not reaching edge. Dorsal ray dividing soon after origin, each branch ending in short bifurcation, none reaching bursal edge. Variation in the final branches of the dorsal ray was noticed, these being sometimes short and close together, at other times longer and more divergent. Spicules 2·83-3·87 mm. long, 1 : 2-2·4 of body length, slender, with wide striated alae extending nearly to tips. Genital cone short, blunt; rudimentary accessory cone present.

Female—Long pointed tail, somewhat dorsally directed. Uteri parallel, uniting near vulva; vagina more or less bent; vulva 0·35-·4 mm. from tip of tail; anus at 0·23-·25 mm. from end of tail. Eggs, 0·14 by·06 mm.

Some specimens were found resembling closely those described above, but having the oesophagus and labial papillae relatively longer.



Figs. 47-50. *Cloacina macropodis*—47, bursa, dorso-lateral; 48, female, posterior end; 49, female head; 50, female, head, lateral. Figs. 51-54. *Cloacina curta*—51, head; 52, female, head, lateral; 53, bursa, dorso-lateral; 54, female, posterior end. Figs. 49, 51 to same scale; 47, 53; 50, 52.

Cloacina curta n. sp.

Figs. 51-54

From *Macropus robustus,* Mount Liebig; Cockatoo Creek.

Short, rather stout (especially females), slightly curved, tapering towards each end. Male, 6·5-7·4 mm. long; female, 7-7·12 mm. Cuticle striated with striations 5 μ apart anteriorly (in male). Four large submedian lips each with elongate papilla of two stout "joints"; two small bilobed lateral lips each with very small conical papilla. Larger papillae project 0·01 mm. and lateral papillae 0·001 mm. from surface. Buccal capsule about as long as wide, with chitinous ring 0·02 mm. in diameter surrounding lower part. Leaf crown with six elements arising from base of ring and projecting inwards. Cervical papillae hair-like, 0·02 mm. long, on small button-like outgrowths, 0·08 mm. from anterior end of worm. Nerve ring 0·2-·25 mm. in male, 0·23-·28 in female from anterior end; excretory pore at 0·28 mm. from head end. Oesophagus 0·45-·5 mm. long, 1 : 13-16 of body length.

Male—Three males which agreed in length, oesophagus, positions of nerve ring, excretory pore and cervical papillae, length of spicules, general shape of bursa and general arrangements of rays, were found to differ in regard to the dorsal ray which in two was asymmetrical and unlike, while in the third it was regular, as figured. Bursa lobes distinct but not deeply separated. Ventral rays joined, parallel, bending forward into ventral lobe; externo-lateral short; medio- and postero-laterals separate at tips, reaching nearly to bursal edge; externo-dorsal arising separately, not reaching edge, being more remote from it than end of externo-lateral is; externo-lateral shorter than externo-dorsal and bursa wider in its vicinity. Dorsal ray bifurcating after about one-third length, in regular type each branch subdivides after the half length into two equal rays, none reaching bursal edge. Spicules 2·35-2·97 mm long, 1 : 2·3-2·9 of body length, curved, with striated alae terminating near tips, with spoon-like ends. Gubernaculum not seen. A pair of lateral prebursal papillae.

Female—Uteri long, parallel; ovejector 0·45 mm. long; vagina wide, bending forwards for about 0·5 mm. before passing back to vulva lying at 0·32 mm. from posterior end of worm and 0·12 mm. in front of anus. Body tapering suddenly from level of anus, 0·2 mm. from tip of short pointed tail. Eggs, 0·19 by ·08 mm.

Cloacina dubia n. sp.

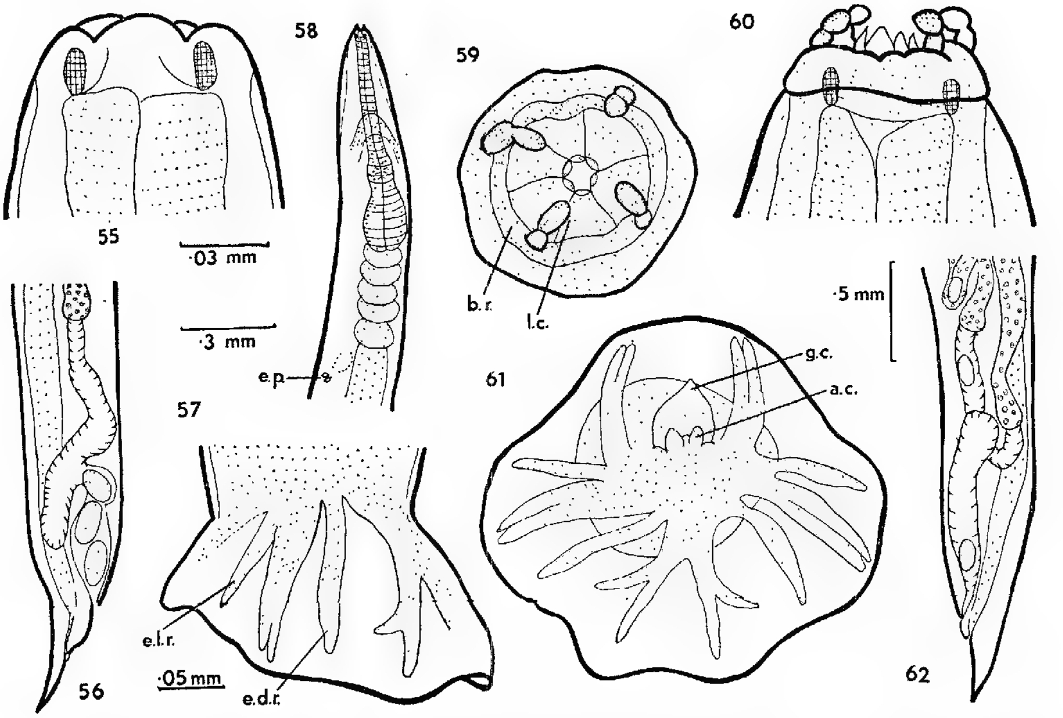
Figs. 55-57

From *Macropus robustus,* Mount Liebig.

Only one male and one female examined. The species is assigned to *Cloacina* only provisionally, since the head characters are not typical of that genus. Male 8·1 mm. long, maximum breadth 0·38 mm., female 8·67 mm. long; slender, tapering towards each end. Cuticle with annulations 0·015 mm. apart. Six low lips. No leaf crown. Buccal capsule with chitinous ring. Oesophagus 0·57-·58 mm. long, 1 : 14-15 of body length, posterior region swollen. Nerve ring 0·29 mm. from head end.

Male—Spicules 3·42 mm., 1 : 2·3 of body length, with narrow striated alae not reaching tip. Ventral lobes of bursa united. Ventral rays separated at tips; externo-lateral slender, shorter than other laterals; medio- and postero-laterals joined, the latter being longer and neither reaching bursal edge; externo-dorsal long, stout, arising separately, extending towards bursal edge as far as does externo-lateral; dorsal ray bifurcated near base, each branch giving off short lateral stem after two-thirds length, inner main branch incurved and not reaching edge of bursa. Genital cone short, blunt.

Female—Body narrows suddenly at level of vulva, ending in fine point bent dorsally. Ovaries in second quarter of body; uteri long, parallel; ovejectors 0·45 mm. long; vagina 0·4 mm.; vulva 0·4 mm. from tip of tail; anus 0·2 mm. from posterior end.



Figs. 55-57—*Cloacina dubia*—55, male, head; 56, female, posterior end; 57; bursa, dorso-lateral. Figs. 58-62. *Cloacina ernabella*—58, anterior end, lateral; 59, head, anterior view; 60, head, lateral; 61, bursa, flattened, posterior view; 62, female, posterior end. Figs. 55, 59, 60 to same scale; 56, 58; 57, 61.

Cloacina ernabella n. sp.

Figs. 58-62

From *Petrogale lateralis*, Mount Liebig; Hermannsburg; Ernabella.

Short, stout, males tapering at both ends, females narrowing more markedly from oesophageal region forwards. Male 8·4-8·6 mm. long, 0·34-·38 mm. in maximum breadth; female 13·4-14·7 mm. 0·58-·66 in maximum breadth. Cuticle finely striate transversely; at anterior end inflated as far back as nerve ring. Mouth collar prolonged into six low lips, four submedian each with large "two-jointed" papilla whose upper "joint" is ovoid and rather larger than lower. Buccal capsule with ring 0·011 mm. long, 0·035 mm. in diameter; floor 0·02 mm. from tip of lips; leaf crown of six elements arising from base of ring; elements bending inwards to surround mouth, with anterior ends bent outwardly. Cervical papillae thread-like, 0·14-0·15 mm. from anterior end. Excretory pore posterior to oesophagus; 1·1 mm. from anterior end. Nerve ring at mid-oesophagus, 0·27-·3 mm. from anterior end. Oesophagus rather long, 0·7-0·76 mm. in male (1 : 11-12 of body length), 0·9-·94 in female (1 : 15 of body length), narrow anteriorly, slight swelling in posterior third followed by bulb. Anterior end of intestine with several lobes.

Male—Bursa with ventral lobes joined, lateral lobes distinct from ventral and dorsal lobes. Ventral rays long, parallel, separate for about two-thirds length; externo-lateral long, thin; laterals long, cleft for about half length; externo-dorsal arising from root of laterals, thin, rather shorter than laterals; dorsal ray wide, soon dividing into two branches, each sending out a lateral, rather shorter than main branch. No ray reaches bursal edge; laterals and ventrals longest. Spicules straight with wide alae almost to their curved tips; 1·8-1·85 mm. long, 1 : 4·6 of body length. Gubernaculum not chitinised but represented by large irregular mass of cells. Genital cone short, rounded; dorsal to opening at base of cone are two small conical structures probably representing an accessory cone.

Female—Body narrows posterior to region of vagina, and very suddenly after vulva to form straight pointed tail. Uteri parallel, uniting near posterior end; ovejectors about 0·5 mm. long; vagina 1·1 mm. long, curving forwards before passing back to vulva. Vulva about 0·45 mm. from posterior end and 0·15 mm. in front of anus. Eggs, 0·17 by 0·07 mm.

Cloacina parva n. sp.

Figs. 67-72

From *Macropus robustus*, Mount Liebig; Cockatoo Creek; Hermannsburg. From *Petrogale lateralis*, Mount Liebig; Hermannsburg; Ernabella.

Slender, short, size varying with age, male 5-10·6 mm. long, female 8-20 mm. Mouth collar with six rather large lips (four submedian, two laterals) and two smaller (a dorsal and a ventral); each submedian with short "two-jointed" papilla; each lateral with small conical papilla. Inwardly from lips six rounded lobes surrounding mouth. Buccal cavity narrow, 0·04 mm. long in large specimens, with chitinous ring forming capsule 0·041 mm. diameter, 0·1 mm. long, thin anteriorly, with plain margin, thicker at base where leaf crown arises to pass forwards closely applied to inner surface of lobes surrounding mouth and projecting beyond them. Oesophagus 0·45-0·65 mm. long, 1 : 10-16 of body length in male; 1 : 20 in female; with wider, more muscular anterior portion about 0·15 mm. long, *i.e.*, nearly half oesophageal length; posterior part with elongate bulb. Cervical papillae about 0·12 mm. from anterior end; nerve ring at about mid-oesophagus, 0·27-·34 mm. from head end; excretory pore near base of oesophagus, 0·46-·52 mm. from anterior end.

Male—Spicules 1·4-3·3 mm. long, 1 : 3-3·2 of body length; slender, with striated alae extending almost to curved tips. Genital cone small; gubernaculum present. Bursa large; dorsal, ventral and lateral lobes distinct. Ventral rays almost reach bursal edge; externo-lateral, lateral and externo-dorsal arise from same root and subequal. Dorsal ray bifurcating just after half-length, each part dividing into two equal branches at mid-length.

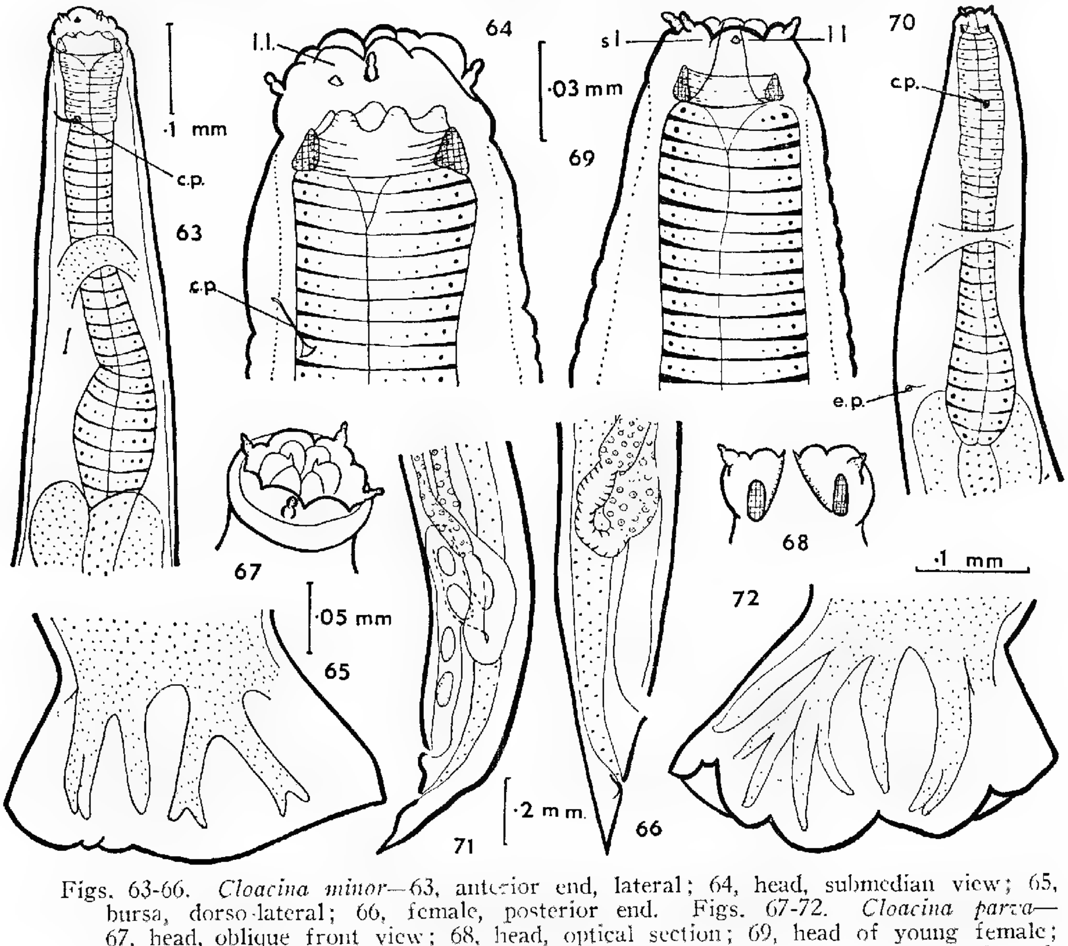
Female—Body narrowing behind vulva, tail pointed. Vagina commencing 0·4 mm. above vulva, then passing forwards for about 0·3 mm. before returning. Vulva 0·16-·18 mm. in front of anus; latter 0·16 mm. from tip of tail.

Cloacina minor n. sp.

Figs. 63-66

From same hosts and from same localities as *Cloacina parva*. Also from *Macropus rufus*, Mount Liebig.

Closely resembling *C. parva* in size, form and general anatomy but differing in the following respects: buccal capsule longer, greater length from top of lips



Figs. 63-66. *Cloacina minor*—63, anterior end, lateral; 64, head, submedian view; 65, bursa, dorso-lateral; 66, female, posterior end. Figs. 67-72. *Cloacina parva*—67, head, oblique front view; 68, head, optical section; 69, head of young female; 70, anterior end, lateral view; 71, female, posterior end; 72, bursa, dorso-lateral. Figs. 64, 67, 68, 69 to same scale; 63, 70; 66, 71.

to floor of capsule, chitinous ring with lobed anterior end; anterior muscular part of oesophagus short, about twice length of buccal cavity; cervical papillae just in front of posterior end of muscular part of oesophagus; spicules 2·12-2·63 mm. long, 1 : 2·3-2·8 of body length; final branches of dorsal ray much shorter, outer branch of each pair short and stout, inner slender and rather longer. Males, about 6 mm. long, maximum breadth 0·24-·31 mm.; female 15 mm., maximum breadth 0·57 mm.; oesophagus 0·5-0·56 mm. long, 1:10-12 of body length in male, 1:29 in female; nerve cord at 0·25-·3 mm. from head end; excretory pore at 0·46-·52 mm.; cervical papillae 0·11-·12 mm. Buccal capsule 0·048 mm. long in male, 0·056 mm. in female. Female: anus at 0·2 mm. and vulva at 0·4 mm. from posterior end.

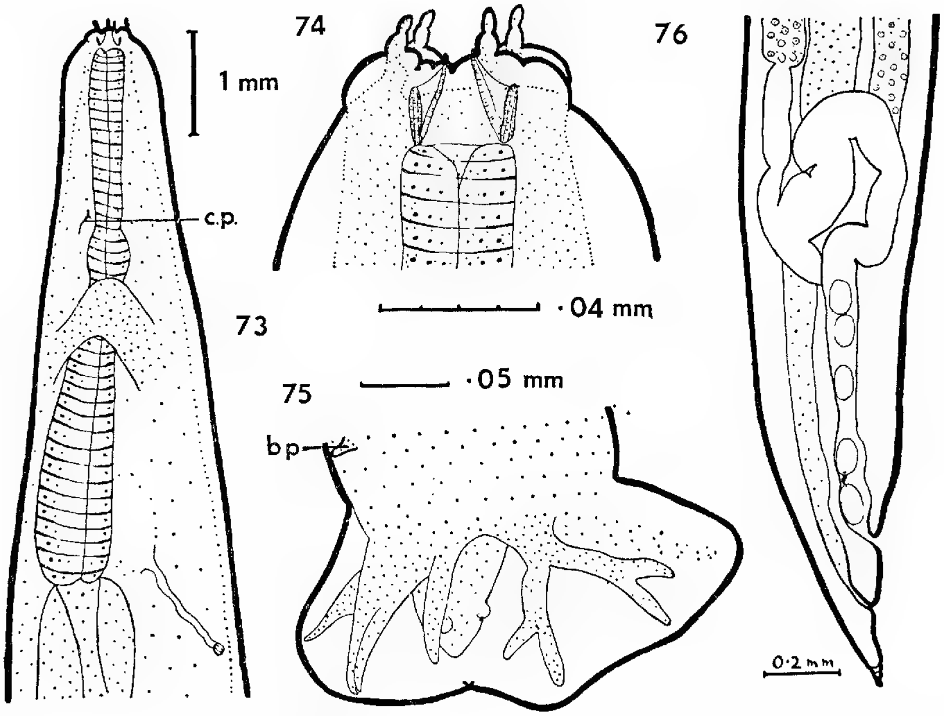
Commonly present along with the preceding species.

Cloacina liebigi n. sp.

Figs. 73-76

From *Macropus rufus,* Mount Liebig.

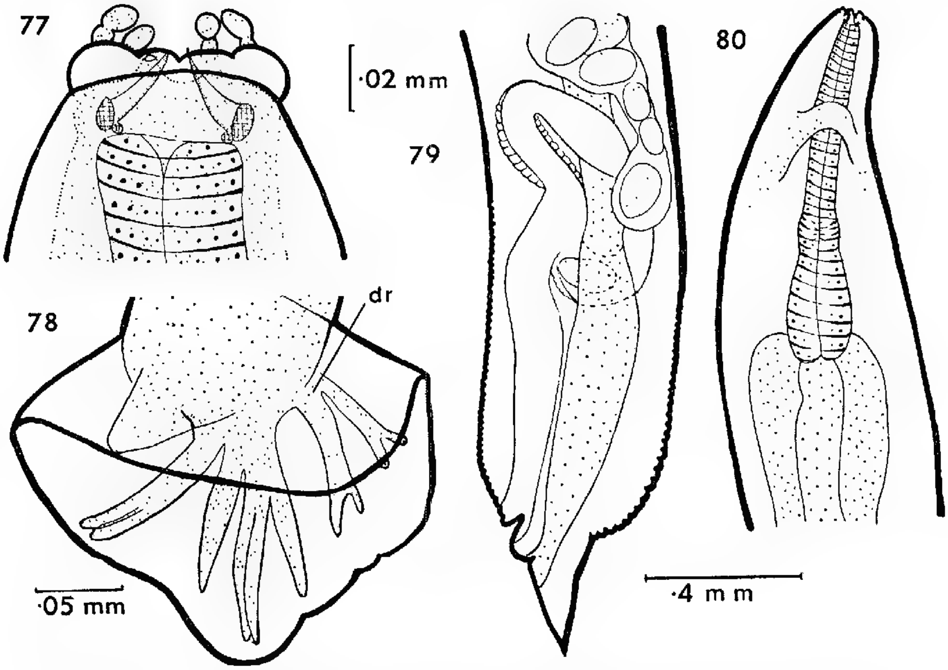
Fairly stout; male 14·75-17·6 mm. long, 0·55-·64 mm. maximum breadth; female 23-24 mm. long, 0·6 mm. broad. Cuticle inflated behind head. Four sub-



Figs. 73-76. *Cloacina liebigi*—73, female, anterior end, lateral; 74, female, head; 75, bursa, dorso-lateral; 76, female, posterior end.

median and two lateral lips, also shallow bilobed process dorsally and ventrally; submedian papillae "two-jointed," slender. Nerve ring about 0·3 mm., and excretory pore at 0·65-·8 mm. from anterior end. Cervical papillae at 0·19 mm. from head end. Buccal capsule 0·02 mm. diameter, walls thin, rather high; leaf crown of six elements arising from base. Oesophagus 0·55 mm. long in male (about 1:30 body length), 0·6 mm. in female (about 1:40 body length), with slight swelling in mid-region immediately in front of nerve ring; gradually widening behind nerve ring, widest just before junction with intestine; anterior end of intestine with thickened walls forming lobes.

Male—Spicules 3·62-4·4 mm. long, 1:4 of body length, slender, with striated alae extending almost to tip. Pair of prebursal papillae. Lobes of bursa not deeply separated from each other, ventral lobes united. Ventral rays parallel, reaching bursal edge; externo-lateral and externo-dorsal equal, long, slender, not reaching edge; laterals parallel, separate for most of length, almost reaching edge; externo-dorsal arising separately. Dorsal ray bifurcates at one-third length, each branch giving off at mid-length a shorter lateral before passing on almost to bursal



Figs. 77 -80. *Cloacina inflata*—77, female, head, lateral; 78, bursa, dorso-lateral; 79, female, posterior end; 80, anterior end, lateral. Figs. 79, 80 to same scale.

edge. Genital cone long, rounded; with two rounded processes on dorsal lip of cloaca.

Female—Body narrows suddenly in region of vagina; tail pointed. Uteri parallel; ovejectors 0·4 mm. long; vagina long, looped forwards; vulva at about 0·4—·45 mm. from tip of tail; anus at 0·2 mm. from end of tail. Eggs, 0·1 by ·07 mm.

Cloacina inflata n. sp.

Figs. 77-80

From *Macropus rufus,* Mount Liebig.

Male 6·7 mm.; female 9-10 mm. Cuticle inflated around anterior end. Two lateral lips; four submedian, each with two-jointed papilla with upper joint larger.

Buccal capsule shallow, with chitinous ring 0·01 mm. long, 0·045 mm. diameter. Nerve ring at 0·27 mm. from head end and surrounding end of first third of oesophagus. Excretory pore and cervical papillae not observed. Oesophagus 0·8 mm. in male (1:8·4 body length), 0·9 mm. in female (1:10·5 body length), with rather elongate terminal bulb in front of which is a slightly swollen region.

Male—Spicules very long, 4·6 mm. 1:1·4 of body length. Lobes of bursa large, well defined. Ventral rays long, slender, not reaching bursal edge, separate for almost entire length; externo-laterals and externo-dorsals shorter, thicker; laterals long, not reaching edge. Dorsal ray bifurcating very soon, each branch dividing near distal end into two short subequal processes not reaching bursal edge. Genital cone long, rounded.

Female—Body narrows suddenly behind anus; tail short, pointed, directed somewhat dorsally. Uteri parallel; vagina wide, straight; vulva 0·35 mm. from tip of tail; anus 0·19 mm. from tip. Eggs large, thick-shelled, 0·17 mm. by 0·09 mm.

DATA SHOWING RATE OF DEVELOPMENT OF TRUNK OF TREE FERN

On 15th November, 1921, close to the foot of Mount Dandenong, Victoria, in company with Mr. A. G. Campbell, of Kilsyth, Victoria, I collected a young tree fern, *Alsophylla australis*, which I brought back and planted in my "brush house" at Blackwood. The tree was found in swampy ground and had a few fronds of only slightly over 3 inches in length.

In November, 1937, the following measurements of this specimen were obtained:

Trunk: Circumference at ground level, 33 inches; at 3 feet above ground, 28 inches; at one foot from crown, 27 inches; height from base to crown, 51 inches.

Fronds: One of the larger ones, 7 feet 3 inches long; thus, when fully expanded, the expanse was nearly 14 feet.

Average annual growth, 3½ inches.

14 July, 1938

E. Ashby

NOTES ON THE GEOLOGICAL FEATURES AND FORAMINIFERAL FAUNA OF THE METROPOLITAN ABATTOIRS BORE, ADELAIDE

By the late WALTER HOWCHIN, Emeritus Professor of Geology and Palaeontology, University of Adelaide, and WALTER J. PARR, F.R.M.S.[1]

Summary

The above bore was sunk on the ground of the Metropolitan Abattoirs Works, situated six miles in a direct line, north by east direction, from the Adelaide Post Office, and rather more than a mile from the Dry Creek Junction. As the sediments passed through proved, at certain levels, very fossiliferous, the Museum and University authorities undertook jointly to secure and bring to Adelaide a drayload of the fossiliferous material for detailed examination. The late Sir Joseph Verco and the senior author spent some time together in passing the loose sandy material through sieves and collecting the fossils so separated.

NOTES ON THE GEOLOGICAL FEATURES AND FORAMINIFERAL FAUNA OF THE METROPOLITAN ABATTOIRS BORE, ADELAIDE

By THE LATE WALTER HOWCHIN, Emeritus Professor of Geology and Palaeontology, University of Adelaide, and WALTER J. PARR, F.R.M.S.[1]

[Read 8 September 1938]

PLATES XV-XIX

CONTENTS

I INTRODUCTION

The above bore was sunk on the ground of the Metropolitan Abattoirs Works, situated six miles in a direct line, north by east direction, from the Adelaide Post Office, and rather more than a mile from the Dry Creek Junction. As the sediments passed through proved, at certain levels, very fossiliferous, the Museum and University authorities undertook jointly to secure and bring to Adelaide a drayload of the fossiliferous material for detailed examination. The late Sir Joseph Verco and the senior author spent some time together in passing the loose sandy material through sieves and collecting the fossils so separated.

It was agreed between Sir Joseph and the senior author that the former should deal with the Mollusca and that the geological features, together with the foraminifera and other fossils, should be described by the latter. It became a matter of deep regret that in consequence of ill-health Sir Joseph had to relinquish this work, but he generously placed his notes on the fossils he had examined at the disposal of Miss N. H. Woods, M.A. (now Mrs. Ludbrook), who had pub-

[1] This paper was begun by the senior author, but, owing to his death, was not completed by him. The plates, with the exception of two or three figures, had been drawn and most of the paper up to the end of the section dealing with the Upper Pliocene foraminifera had been written. At the request of the Director of the South Australian Museum, to which the late Professor Howchin bequeathed his collection of fossils, Mr. Parr undertook the completion of the paper. In doing so, he has revised, as far as possible, the earlier determinations and utilized Professor Howchin's notes, and accepts joint responsibility for the work.—EDITOR.

lished some original observations in the determination of new species in the Transactions of this Society.

It is unfortunate that a scientific examination was not made during the course of the boring operations, but the main geological horizons are so well defined lithologically and palaeontologically that it is an easy matter to classify the section into three main geological ages.

The thanks of the authors are due to J. H. Horwood & Co. Ltd, the contractors who carried out the work at the Abattoirs Bore, and especially to Mr. W. J. Barker, Managing Director of the company, who in response to the senior author's request, courteously supplied the boring log which follows.

II CONTRACTOR'S TABLE OF STRATA

Total Ft. Bored	Thickness of Strata, Ft.	Nature of Strata
26	26	Clay
30	4	Sand rock
80	50	Stiff sandy clay
110	30	Light brown clay
120	10	Sticky clay
161	41	Stiff swelling clay
180	19	Sandy clay
190	10	Swelling clay
196	6	Yellow sandy clay
208	12	Coarse yellow sand & gravel
222	14	Stiff reddish clay
225	3	Sticky red clay
235	10	Fine red sand
242	7	Coarse sand
250	8	Fine and coarse sand
255	5	Sand rock
300	45	Stiff sandy clay
310	10	Stiff yellow clay
320	10	Stiff yellow clay, getting darker
323	3	Stiff green clay
333	10	Black clay with particles of decaying wood
341	8	Black sand and pebbles
368	27	Fine grey sand
381	13	Grey sand, showing fossils
392	11	Fine white sand and fossils
397	5	Grey to white sand and fossils
410	13	Grey sand and fossils
430	20	Grey sand and shells, which are smaller and not so plentiful
450	20	Sandy clay, some cemented
470	20	Sandy clay and fine sand with small shells
481	11	Stiffer clay and fossils
490	9	Stiff clay and fossils, with 5 ft. of grey sand
500	10	Clay, turning to "cliff rock" (fine - grained calcareous sandstone)
545	45	Yellow fossilized "sand rock" to "cliff rock"
555	10	Yellow "cliff rock," getting lighter
575	20	White fossilized "sand rock"
610	35	Soft dark blue fossilized "sand rock"
635	25	Soft white fossilized "sand rock"
640	5	Blue clay
656	16	Stiff blue clay
673	17	Very sticky blue clay
705	32	Fossilized blue clay with layers of fossilized rock, getting lighter in colour
710	5	Yellow fossilized sand rock to sticky yellow clay
730	20	Yellow fossilized sand rock
810	80	Alternate layers of hard and soft yellow fossilized sand rock
820	10	Yellow fossilized sand rock
		BOTTOM OF BORE

(NOTE—The word "fossilized," used in the above table, evidently indicates that fossils are present.—W. J. P.)

III STRATIGRAPHICAL DIVISIONS

Section 1. RECENT to PLEISTOCENE: From surface to 341 ft. Alluvial sand and gravel, some very coarse, representing the superficial deposits of the Adelaide Plains.

Section 2. UPPER PLIOCENE: From 341 to 500 ft. Mostly a clean white sand with a shallow-water marine fauna, generally of Recent aspect. It was from this horizon that the large quantity of material to which reference has been made was obtained.

Section 3 MIOCENE: From 500 to 820 ft. (bottom of bore). Geologically uncomformably related to the overlying sediments, carrying a distinctive fauna which is comparable with that of the lower portion of the Miocene of Victoria. Two horizons are represented in the material examined, the upper, between 575 and 620 feet, and the lower, which carries a number of species characteristic of the Lower Miocene of Batesford and Muddy Creek, in Victoria, between 710 and 820 feet.

The geological section revealed in the present bore agrees essentially with others which have been obtained by borings within the great Adelaide sunken basin, antecedently described in the Dry Creek and Croydon Bores, and, lately, from the Brooklyn Park, Glanville, and Cowandilla Bores (Howchin, 1935 and 1936), in which the geological features of the group have been under discussion.

NOTE.—The senior author has previously recognised a geological stage of Upper Pliocene age, in the Adelaide Basin, to which he gave the name of Adelaidean. This consists of fossiliferous marine beds occupying a limited area along the western and north-eastern sides of the city of Adelaide, following the direction of Cowandilla, Brooklyn Park, Lockleys, Croydon, Glanville, the Metropolitan Abattoirs, Dry Creek, and Salisbury. The occurrence of these beds in the Brooklyn, Glanville, and Cowandilla Bores is dealt with at length and an explanation of their origin given in Professor Howchin's papers published in the Transactions of this Society for 1935 and 1936. The beds now recorded from the Abattoirs Bore as of Upper Pliocene age belong to the same stage.

Mrs. N. H. Ludbrook, M.A. (née Woods), who has examined the pelecypods from the Abattoirs Bore and the mollusca of the Hindmarsh Bore, recently (Rept. A.N.Z. Ass. Adv. Sci., 1937 Meeting, pp. 444-446) expressed the view that the beds assigned by Howchin to the Upper Pliocene (Adelaidean) are all of Lower Pliocene (Kalimnan) age. She states: "In no case are the 'Adelaidean' beds proved either to underlie or overlie the Lower Pliocene, though Howchin (1936) has suggested that they may overlie the Lower Pliocene in the Cowandilla Bore. Accumulation of evidence made possible by the extensive boring operations in search of water in the neighbourhood of Adelaide during recent years has shown that faulting has taken place on a large scale, details of which it is hoped will be available in the future; it is no longer completely improbable that such faulting could account for the position of the 'Adelaidean' beds, while they may be synchronous with other beds of Lower Pliocene age in Southern Australia. Furthermore, it is suggested that sufficient attention must be given to the change in the fauna, due to varying conditions, at different localities along a coastline; this can be demonstrated along any coastline today."

On the evidence of the foraminifera and with knowledge of the foraminiferal faunules occurring in the Lower Pliocene (Kalimnan) at Kalimna, and at McDonald's and Forsyth's, near Hamilton, in Victoria, I am in agreement with Professor Howchin's reference of the upper marine beds of the Abattoirs Bore to the Upper Pliocene. It might be suggested, as Mrs. Ludbrook has done in regard to the mollusca, that facies may account for the differences between the assemblage of foraminifera in the Abattoirs Bore and those of the Victorian Kalimnan localities. This does not, however, appear a satisfactory explanation, as the beds at the Victorian localities mentioned are all shallow-water, more or less sandy clays and facies alone would not account for the differences between the foraminifera of the present bore and those of the Victorian localities. The Victorian beds contain certain restricted species such as *Flintina intermedia* (Howchin), which occurs at Kalimna as well as in the Hamilton district and elsewhere, and *Fabularia howchini* Schl. (Hamilton district only), and the assemblages otherwise differ in many respects from that in the Abattoirs Bore. On the other hand, we have in the Bore very distinctive forms such as *Flintina triquetra* (Brady) and *Nubecularia lucifuga* Defr., var *lapidea* Wiesner, which have not been previously recorded fossil and have not been met with in the Kalimnan of Victoria. The presence of several genera of the family *Peneroplidae* also gives the faunule a strong Recent aspect. Still further evidence is provided by the record by Professor Howchin of the occurrence, in the Adelaidean of the Brooklyn Park, Glanville, and Cowandilla Bores, of *Cribrobulimina polystoma* (P. & J.), hitherto known only from the Pleistocene and Recent seas of southern Australia.

Mr. F. Chapman has informed me that he is also in agreement with Professor Howchin's opinion that the Adelaidean beds are younger than Kalimnan. He has kindly furnished the following note.

> "The Adelaidean series of the Abattoirs and Hindmarsh Bores show a molluscan fauna similar to that of Hallett's Cove, largely of a Recent aspect and with such older species as *Neodiastoma provisi* (Tate) (not Kalimnan). The *Eucrassatellae* I examined for Howchin were not in every case typical of the Kalimnan forms, many showing annectant characters between the Upper Muddy Creek and the Jemmy's Point, Kalimna, forms, whilst others again were non-typical of either.
>
> "In the present case the position in the vertical scale appears to be better indicated by the comprehensive series of the foraminifera, which comprise so many species new to the Kalimnan of the type locality and the Muddy Creek area."

It will be noted that Mr. Chapman disagrees with Professor Howchin's reference (1935, p. 85) of the Hallett's Cove beds to the Kalimnan.

In the Abattoirs Bore no beds of Kalimnan age have been recognised. It is possible that they may be represented between 500 and 575 feet, but fossil evidence on this point is lacking, the foraminifera examined coming from between 341 and 500 feet and from 575 feet downwards.

W. J. P.

IV SYSTEMATIC ACCOUNT OF THE FORAMINIFERA

PART 1 UPPER PLIOCENE SPECIES

Family VALVULINIDAE

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA PACIFICA Cushman

Clavulina pacifica Cushman, 1924, p. 22, pl. vi, figs. 7-11; 1937, p. 25, pl. iii, figs. 17, 18.

This species was described from Pago Pago Harbour, Samoa, and is well distributed through the warmer portions of the Indo-Pacific region in shallow water. It has not been previously recorded as a fossil. Australian Recent occurrences are at Murray Island, Torres Strait, Port Denison, Queensland, and Geraldton Harbour, Western Australia. It is rare in the Abattoirs and Cowandilla Bores.

Clavulina difformis Brady

Clavulina angularis d'Orbigny, var. *difformis* Brady, 1884, p. 396, pl. xlviii, figs. 25-31.

C. difformis Brady Cushman, 1921, p. 156, pl. xxxi, figs. 2 *a, b;* 1937, p. 23, pl. iii, figs. 4-10.

Like the preceding species, this is widely distributed as a living form in the Indo-Pacific region and is frequently associated with *C. pacifica.* It may be distinguished from *C. pacifica* by its coarse-textured shell-wall; the test is also polygonal in transverse section, while that of *C. pacifica* is triangular. There is one example, not quite perfect but otherwise typical, from the present bore. The junior author has Recent specimens from the coast of Victoria.

Clavulina multicamerata Chapman
(Pl. xvi, fig. 12)

Clavulina parisiensis d'Orbigny var. *multicamerata* Chapman, 1909, p. 127, pl. ix, fig. 5.

C. multicamerata Chapman: Parr, 1932, p. 4, pl. i, figs. 4, 5. Cushman, 1937, p. 24, pl. iii, figs. 13-16.

This was described by Chapman from Shoreham, Westernport, Victoria, as a variety of *C. parisiensis*, and was later given specific rank by Parr. It is common in shallow water on the southern coast of Australia, and also occurs as a fossil in the Upper Beds (of Lower Pliocene age) at Muddy Creek, Victoria. Verco dredged some fine examples off the Neptune Islands (South Australia). In the Abattoirs Bore the species is moderately common. A noteworthy feature is that some of the specimens are limited to the triserial portion of the test, when, but for the presence of the adult form, they would be referred to the genus *Valvulina*. The figured specimen is a slender, delicate one, the remainder being perfectly typical.

Family MILIOLIDAE

Genus Quinqueloculina d'Orbigny, 1826

Quinqueloculina agglutinans d'Orbigny
(Pl. xv, fig. 1)

Quinqueloculina agglutinans d'Orbigny, 1839, p. 195, pl. xii. figs. 11-13. Cushman, 1929, p. 22, pl. i, figs. 1 *a-c*.

This species is represented by four very typical examples, one of which measures 1·7 mm. in length. It is a common form in shallow water in the West Indian region.

Quinqueloculina ammophila Parr
(Pl. xv, figs. 3, 4)

Quinqueloculina ammophila Parr, 1932, p. 8, pl. i. figs. 10 *a, b;* text fig. 1 E. Chapman and Parr, 1935, p. 3.

There are five examples of this species which was described from shallow water in Westernport Bay, Victoria. Like *Q. agglutinans,* the test is coarsely arenaceous, but it is much compressed, with strongly depressed sutures, and the aperture has a single plate-like tooth, so it may readily be distinguished from the older species.

QUINQUELOCULINA SEMINULUM (Linné)

Serpula seminulum Linné, 1767, p. 1,264.
Quinqueloculina seminulum (Linné): Cushman, 1929, p. 24, pl. ii, figs. 1, 2.

This is represented by a few fine examples.

QUINQUELOCULINA VULGARIS d'Orbigny

Quinqueloculina vulgaris d'Orbigny, 1826, p. 302, No. 33. Schlumberger, 1893, p. 207, text figs. 13, 14; pl. ii, figs. 65, 66. Cushman, 1929, p. 25, pl. ii, figs. 3 *a-c*.

This is closely related to the previous species but is more rotund in outline, being about as wide as long and with well-defined sutures. It is rather scarce in the bore, but is a common form in Recent shore sands from Victoria and South Australia.

QUINQUELOCULINA BOSCIANA d'Orbigny
(Pl. xv, fig. 15)

Quinqueloculina bosciana d'Orbigny, 1839, p. 191, pl. xi, figs. 22-24.
Miliolina bosciana (d'Orb.): Chapman, 1900, p. 177, pl. i, fig. 7.

The test of this species is comparatively long and narrow, as in *Triloculina oblonga,* but the chambers are arranged on a quinqueloculine plan and the sutures are oblique. The types were from shore sand, Cuba, and it is common on the Victorian coast. The three examples from the Abattoirs Bore are typical.

QUINQUELOCULINA LAMARCKIANA d'Orbigny

Quinqueloculina lamarckiana d'Orbigny, 1839, p. 189, pl. xi, figs. 14, 15. Cushman, 1929, p. 26, pl. ii, figs. 6 *a-c*.

The present specimens are not typical, being intermediate between this species and *Q. vulgaris,* but are nearer the former. In its typical form, *Q. lamarckiana* has the chambers triangular in transverse section, the margins to the test being subacute. The bore examples are poorly developed and have much blunter angles. The two forms occur together in shallow water on the coasts of South Australia and Victoria.

QUINQUELOCULINA POLYGONA d'Orbigny
(Pl. xvi, fig. 14)

Quinqueloculina polygona d'Orbigny, 1839, p. 198, pl. xii, figs. 21-23. Cushman, 1929, p. 28, pl. iii, figs. 5 *a-c;* 1932, p. 25, pl. vi, figs. 5, 6.

This species is common in the bore material, the examples being similar in form to that figured by Cushman from off Levuka, Fiji (1932, *loc. cit.,* fig. 6). The types were from the West Indies and the species is common in the tropical Pacific and also on the southern coast of Australia, in shallow water.

QUINQUELOCULINA LIMBATA d'Orbigny

Quinqueloculina limbata d'Orbigny, 1826, p. 302, No. 20. Fornasini, 1905, p. 66, pl. iii, fig. 9.

Miliolina limbata (d'Orb.): Wiesner, 1923, p. 45, pl. vi, fig. 51.

Fornasini's figures of this species, based on the drawings by d'Orbigny in the "Planches inédites," show it to be nearly three times as long as broad, with the chambers flattened and the periphery somewhat truncate. The outside margin of each chamber is ornamented with five or six strong, longitudinal costae. The aperture is produced and a little flared, with a simple tooth. The types were from the Red Sea. The example figured by Wiesner from the Adriatic is proportionately shorter, being about twice as long as broad, and the chambers are rounded in transverse section. The five specimens from the Abattoirs Bore are about twice as long as broad, but otherwise agree fairly well with Fornasini's figures, except that the number of costae to a chamber varies from five to two.

Quinqueloculina adelaidensis sp. nov.

(Pl. xv, figs. 5, 7)

Description—Test elongate, slender, quinqueloculine; chambers rounded; sutures slightly depressed; apertural end extended into a long cylindrical neck; aperture circular with a phialine lip and simple tooth; wall thin, with a rough surface, composed of minute quartz grains on a base of porcellaneous shell material. Length, 1·1 mm.; breadth, 0·3 mm.; thickness, 0·25 mm.

Holotype in Howchin Collection, South Australian Museum.

Seven samples of this species were found in the material from the bore. We have not previously met with anything closely resembling it in any of the Recent or fossil Australian material we have examined nor is it figured by Millett, Heron-Allen and Earland, or Cushman in their papers on Indo-Pacific Recent foraminifera. Cushman (1932, p. 23, pl. v, fig. 12) has figured, under the name of *Quinqueloculina* cf. *gracilis* d'Orb., a specimen from the tropical Pacific which is perhaps nearest to the present form, but differs from it in having a polished porcellaneous test with slight traces of longitudinal markings.

Genus SPIROLOCULINA d'Orbigny, 1826

SPIROLOCULINA ANTILLARUM d'Orbigny

Spiroloculina antillarum d'Orbigny, 1839, p. 166, pl. ix, figs 3, 4. Cushman, 1929, p. 43, pl. ix, fig. 3. Parr, 1932, p. 9, pl. i, fig. 11.

This species was described as a Recent form from the West Indies and is widely distributed through the Indo-Pacific region, particularly fine examples, similar to the one figured by Parr, occurring on the South Australian coast. As a fossil, it is found in the Lower Beds, of Lower Miocene age, at Muddy Creek, Victoria.

Spiroloculina lapidigera sp. nov.

(Pl. xv, fig. 10)

Spiroloculina sp. cf. *arenaria* Brady: Parr, 1932, p. 220, pl. xxii, figs. 41 *a, b.* Howchin, 1936, p. 4.

Description—Test irregularly elliptical; periphery broadly rounded; chambers comparatively few, oval in transverse section, evenly curved and each larger in diameter than its predecessor, resulting in the central portion of each face being depressed, the final chamber embracing its predecessor at each end and with the apertural end produced into a short neck, with a phialine lip; the aperture is rounded and with a simple tooth. The wall is composed of agglutinated sand grains, mostly of comparatively large size; the larger grains are strongly defined and highly coloured as black, saffron, and transparent, which show conspicuously on the white cement background. Length, up to 1·8 mm.; breadth, 1·5 mm.; thickness, 0·52 mm.

Holotype from Upper Pliocene, Cowandilla (Government) Bore, 420 feet, in Howchin Collection, South Australian Museum. There are three examples from the Abattoirs Bore.

This striking species was recorded by the senior author *(loc. supra cit.)* as being one of the most remarkable objects in the Upper Pliocene of the Cowandilla Bore, from which the holotype has been selected. Parr has also recorded and figured it, also under the name of *Spiroloculina* sp. cf. *arenaria* Brady, as a Recent form from Westernport Bay, Victoria. It is, however, very distinct from *S. arenaria,* from which it may be distinguished by the much larger aperture, shorter apertural neck, depressed sutures, and the concave centre of the test.

Genus Hauerina d'Orbigny, 1839

Hauerina ornatissima (Karrer)

(Pl. xv, figs. 8, 9)

Quinqueloculina ornatissima Karrer, 1868, p. 151, pl. iii, fig. 2.
Hauerina ornatissima (Karrer): Brady, 1884, p. 192, pl. vii, figs. 15-22.

This beautiful species is represented in the bore by a single example measuring about 0·4 mm. in diameter. It is very well defined, both by its unique ornamentation and its cribrate aperture. Its usual Recent habitat is in shallow waters of tropical seas, its range extending from the West Indies through the tropical Pacific to the Kerimba Archipelago, off Portuguese East Africa. It occurs on the Great Barrier Reef and in Northern Australian waters, but has not been previously recorded either as a living form or as a fossil from South Australia. It is, therefore, interesting to note that, in addition to the specimen from the Abattoirs Bore, a similar example was met with in the Upper Pliocene of the Cowandilla Bore. Figures are given of both specimens.

Genus Triloculina d'Orbigny, 1826

Triloculina oblonga (Montagu)

Vermiculum oblongum Montagu, 1803, p. 522, pl. xiv, fig. 9.
Triloculina oblonga (Montagu): Cushman, 1929, p. 57, pl. xiii, figs. 4, 5.

Test long and narrow, of a porcellaneous white, showing three visible chambers and a simple or bifid tooth, are the fundamental characters on which considerable variations of a minor kind have been based, resulting in numerous synonyms. According to the published records, it is very widely distributed. In the present bore it is moderately common.

Triloculina tricarinata d'Orbigny

Triloculina tricarinata d'Orbigny, 1826, p. 299, No. 7; Modèles, No. 94; Cushman, 1929, p. 56, pl. xiii, figs. 3 *a-c*.

The test, like the preceding species, has three visible chambers, very distinctly triangular, with a sharp periphery. It is common in shallow water on the coasts of South Australia and Victoria. In the Abattoirs Bore examples are scarce, and whilst distinctly tricarinate, the segmental angles are a little more rounded than is generally the case. It occurs also in the Cowandilla Bore.

Triloculina cultrata (Brady)

Miliolina cultrata Brady, 1881, p. 45; 1884, p. 161, pl. v, figs. 1, 2.
Triloculina cultrata (Brady): Parr, 1932, p. 10, pl. i, figs. 14 *a, b*.

The records of this species, with the exception of that by Parr from off Black Rock, Victoria, are from tropical shallow water. It is here represented by a single example, which appears to be the first occurrence as a fossil.

Genus Flintina Cushman, 1921

Flintina triquetra (Brady)

(Pl. xv, figs. 11-13)

Miliolina triquetra Brady, 1879, p. 268; 1884, p. 181, pl. viii, figs. 8-10.
Flintina triquetra (Brady): Chapman and Parr, 1935, p. 4, pl. i, figs. 2 *a, b*.

This species has hitherto been known only as a Recent form and is one which has been rarely recorded. In the bore it is, therefore, remarkable that it is very common, over 200 fine examples having been obtained, the largest measuring 4·2 mm. The average diameter of the bore specimens is about 3·3 mm., or more than three times the dimensions given by Brady. Brady's records were from Bass Strait, 38 fathoms; Torres Strait, 155 fathoms; and Humboldt Bay, Papua, 37 fathoms.

It will be noted that, in the figures we give, the aperture is much larger and at the end of a shorter neck than those figured by Brady. This is merely due to the much larger size of our specimens, as we find, in a series of specimens from Bass Strait, the largest specimens (larger than those figured by Brady) have an aperture similar to that of the bore examples, the apertural neck and aperture becoming respectively shorter and larger with the increase in size of the test. Besides the bore specimens, the senior author has had the species from Pliocene beds to the south of Hallett's Cove, South Australia.

Genus PYRGO Defrance, 1824

PYRGO sp. cf. BULLOIDES (d'Orbigny)

(Pl. xv, fig. 6)

There are three specimens which, in external characters, bear a considerable resemblance to the European Eocene species, *P. bulloides*. The example figured has since been accidentally broken, showing the shell to be megalospheric, with a large proloculus, 0·6 mm. in diameter, followed by three chambers added in planes 180° apart.

Family OPHTHALMIDIIDAE

Genus NODOBACULARIELLA Cushman and Hanzawa, 1937

Nodobaculariella cultrata sp. nov.

(Pl. xv, fig. 14, *a*, *b*)

Description—Test strongly compressed, periphery subacute with a thin keel; chambers in the early portion consisting of an ovoid proloculus, directly followed by a planospiral chamber extending half way round the proloculus, remaining chambers roughly triangular in outline with the aboral end recurved, inflated in the middle, not generally involute, the centre of each face of the shell being depressed and showing portions of the earlier whorls, three chambers to the adult whorl; wall ornamented by numerous, fine costae which are parallel to the outside margin; aperture elongate, narrow, terminal, with a slight everted lip. Maximum diameter, 0·65 mm.

Holotype in Howchin Collection, South Australian Museum.

This genus has only very recently been described, and it is therefore of much interest to find it typically represented in the Abattoirs Bore. Until its early stages were studied by Cushman and Hanzawa, it was identified with the genus *Vertebralina*, which has a different plan of growth, the early chambers being arranged in a trochoid spiral.

N. cultrata is represented by a single example in the bore material, but the same form is common in the Lower Beds (of Lower Miocene age) at Muddy Creek, Victoria, so we feel justified in dealing with it here as new. The only species resembling it is *N. atlantica*, described by Cushman and Hanzawa (1937, p. 42, pl. v, figs. 7, 8) from the eastern coast of United States. The chambers of this are proportionately shorter and it lacks the knife-like keel of *N. cultrata*, which also differs in having a long, narrow aperture of even width.

Genus NUBECULARIA Defrance, 1825

NUBECULARIA LUCIFUGA Defrance

Nubecularia lucifuga Defrance, 1825, Dict. Sci. Nat. (Strasburg, 1816-1830), vol. xxv, p. 210; Atlas Zooph., pl. xliv, fig. 3. Brady, 1884, p. 134, pl. i, figs. 11, 13-16, ?9, 10 (*non* 12).

This species, which is so common and finely developed in shallow water in Gulf St. Vincent, is well represented in the bore material. The protean forms assumed by it in present-day seas are here present and both free and attached specimens occur. In one case, a colony of seven individuals exhibiting a *Placopsilina*-like plan of growth was found attached to a sand grain measuring 5 mm. x 3 mm.

NUBECULARIA LUCIFUGA Defrance var. LAPIDEA Wiesner
(Pl. xv, fig. 2; pl. xvi, figs. 1-3)

Nubecularia lucifuga Brady (*non* Defrance), 1884, pl. i, fig. 12. Millett, 1898, pl. v, fig. 7.

N. lucifuga Defrance var. *lapidea* Wiesner, 1923, p. 94, pl. xix, fig. 282.

Normally the test of *N. lucifuga* is wholly porcellaneous, although Brady, in the "Challenger" Report, noted that the shell at times shows a tendency to agglutinate sand grains, as in the Miliolidae. His fig. 12, on pl. xv, represents one such example. According to Brady (1884, p. 134), the examples of *N. lucifuga* figured by him were from the coast of Tripoli and from the beach near Melbourne, Australia, but he did not give the locality for each specimen. Nuttall (1927, p. 211), in his paper giving the localities whence the foraminifera figured in the "Challenger" Report were derived, states that figures 13-15 represent specimens from the Gulf of Bombah, Tripoli. It is probable that the remaining figured specimens were from Australian waters. The locality given, "beach, near Melbourne," suggests that the material was some of that studied by Parker and Jones (1865, List No. 30) and which Parr has stated (1932, p. 1) was almost certainly from the coast of South Australia. We have seen nothing like the specimens under discussion in any Victorian material, although they can be matched in almost any shallow water gathering from Gulf St. Vincent.

The agglutinated form of *N. lucifuga*, to which Wiesner has given the name of var. *lapidea*, is common in Gulf St. Vincent, and Parr has found it to be frequent in shore sand at Port Fairy, Victoria, where it occurs to the exclusion of the typical form. Outside Australian waters, it seems to be of very rare occurrence, the only records of it appearing to be the two given above. Millett's was from the Malay Archipelago, and that of Wiesner, who named the variety on a single specimen, from the Adriatic.

Specimens occur fairly commonly in the Abattoirs and Croydon Bores, the best examples being obtained from the latter. Most of them have been attached during life, but one, apparently free, specimen, which is figured (pl. xv, fig. 2) was found. This shows an irregular slit-like aperture, which has not been observed in any of the adherent examples. The shell of var. *lapidea* is more strongly built and generally larger than is usual in the typical form of *N. lucifuga*. In the bore, incomplete specimens 5 mm. in length were met with. The sand grains incorporated in the wall consist of clear quartz and, in cross sections, are seen to be embedded in the cement but have an even face at the surface.

Family LAGENIDAE

Genus Dentalina d'Orbigny, 1826

Dentalina obliqua (Linné)

Nautilus obliquus Linné, 1767, p. 1,163; 1788, p. 3,372, No. 14.
Nodosaria obliqua (Linné): Fornasini, 1902, p. 36.

There is one incomplete example, 3 mm. in length and agreeing closely with the figure given by Gualtieri, on which Linné based this species. We are indebted to Dr. J. A. Cushman for a photograph of Gualtieri's plate on which the species is figured.

Family POLYMORPHINIDAE

Genus Guttulina d'Orbigny, 1826

Guttulina problema d'Orbigny

Guttulina problema d'Orbigny, 1826, p. 266, No. 14, Modèles, No. 61. Parr and Collins, 1937, p. 191, pl. xii, fig. 1.

There are two examples of this widely-distributed species, the larger of which is 0·95 mm. in length.

Guttulina regina (Brady, Parker, and Jones)

Polymorphina regina Brady, Parker, and Jones, 1870, p. 241, pl. xli, figs. 32 *a, b*.
Guttulina regina (B., P., & J.): Parr and Collins, 1937, p. 193, pl. xii, fig. 5; text figs. 1-7.

This costate form is a well-known Australian species, the type locality of which is Storm Bay, Tasmania. In the Upper Pliocene of the Abattoirs Bore it is rare and small.

Genus Sigmoidella Cushman and Ozawa, 1928

Sigmoidella elegantissima (Parker and Jones)

Polymorphina elegantissima Parker and Jones, 1865, p. 438. Brady, Parker, and Jones, 1870, p. 231, pl. xl, figs 15 *b, c (non a)*.
Sigmoidella elegantissima (P. & J.): Parr and Collins, 1937, p. 206, pl. xiv, fig. 9.

Like the preceding, this species was described from Australian coastal waters, in which it is common. It is also found in Australian Tertiary deposits from the Lower Miocene upwards. In the present bore one good-sized specimen and several smaller ones were obtained.

Sigmoidella kagaensis Cushman and Ozawa

Polymorphina elegantissima Brady, Parker, and Jones, 1870 (pars), p. 231, pl. xl, fig. 15 *a*.
Sigmoidella kagaensis Cushman and Ozawa: Parr and Collins, 1937, p. 207, pl. xiv, fig. 10.

This species was described from the Pliocene of Japan. It is widely distributed in the Western Pacific, in moderately shallow water, and occurs frequently on the Australian coast. Its geological range in Australia is the same as that of *S. elegantissima*. It is rare in the bore material.

Family NONIONIDAE

Genus Elphidium Montfort, 1808

Elphidium advenum (Cushman)

Polystomella subnodosa Brady *(non Robulina subnodosa* Münster), 1884, p. 734, pl. cx, figs. 1, *a, b*.
P. advena Cushman, 1922, p. 56, pl. ix, figs. 11, 12.
Elphidium advenum (Cushm.): Cushman, 1930, p. 25, pl. x, figs. 1, 2.

The types of this species were from the Tortugas region, off southern Florida, U.S.A. Brady's specimens, with which those from the Abattoirs Bore are in close agreement, were from two "Challenger" Stations between Papua and Australia.

Elphidium rotatum sp. nov.

(Pl. xvii, figs. 1, 2, 4)

Elphidium (?) *macellum* (Fichtel and Moll): Howchin, 1936, p. 3.

Description—Test strongly compressed, slightly umbonate, sides sloping evenly in most cases from the umbo to the subacute periphery, occasionally the sides are slightly depressed near the margin; chambers very numerous, up to 56 in the adult whorl, not inflated, of nearly uniform height throughout; sutures distinct, limbate and raised, recurved at the outer end, except in the last quarter whorl, when they are straight; retral processes extending as cross bars across the full width of the chamber, 30 or more in the adult chamber, towards the outer end of the chamber the retral processes are crossed by one or more ridges running parallel to the sutures and so forming a delicate, cross-lines meshwork on the marginal surface of the chamber; umbo with numerous small irregular pits, aperture a series of small rounded openings at the base of the sharply-triangular apertural face. Diameter, up to 2·9 mm.; thickness, to 0·7 mm.

Holotype from shore sand, Kingston, South Australia, collected by Dr. W. G. Torr and in Howchin Collection, South Australian Museum.

In Part II of the senior author's series of geological notes on the deep borings in the Adelaide Basin *(loc. supra cit.)*, he drew attention to the occurrence of a species in the Cowandilla Bore which he doubtfully referred to *Elphidium macellum*. Subsequently, on examining some shore sands from Kingston, South Australia, collected many years ago by Dr. W. G. Torr, the same form was found to be very common. When further examples of a like kind were met with in the Abattoirs Bore, it was decided to give them specific distinction. The slimness of the test, as well as the sharp peripheral edge, renders the shells liable to injury by weathering, which is seen in the Recent specimens in part, as well as the fossils. Under such circumstances, it has been deemed advisable to select a Recent example as the holotype.

As already noted, the species is common in the shore sand from Kingston. As a fossil, it appears to be limited to the Upper Pliocene in the Adelaide Basin, where it is of rare occurrence, one example having been found in the Abattoirs Bore and another in the Cowandilla Bore. The former is 2·0 mm. in diameter, and the latter 1·80 mm.

Elphidium adelaidense sp. nov.

(Pl. xviii, fig. 7; pl. xix, figs. 5, 6)

Description—Test strongly compressed and umbonate, periphery acute, but not keeled; chambers very numerous, 40 or more in the adult whorl, of about uniform height throughout, low and slightly recurved; very slightly inflated; sutures indistinct; retral processes numerous, up to 22 in the adult chamber, extending across the surface of the chamber, or occasionally only a little forward and backwards from the suture line and so forming a double series of shallow pits bordering each chamber, the large umbo with numerous, very shallow, irregular pits; aperture a series of small, obscure, rounded openings at the base of the sharply-triangular apertural face. Diameter, up to 2·9 mm.; thickness, to 1·1 mm. Usually the specimens do not exceed 1·7 mm. in diameter.

Holotype in Howchin Collection, South Australian Museum.

This species is not uncommon in the Upper Pliocene of the Abattoirs Bore and appears also to occur in the Miocene of the bore. The most closely related species is possibly *E. chapmani*, described by Cushman (1936 (2), p. 80, pl. xiv, figs. 6 *a, b)* from the Miocene of Neumerella, Victoria and herein recorded from the Miocene of the bore. This is a much smaller form, with fewer chambers (25-30), a proportionately thicker test, and a different development of the retral processes.

Genus Polystomellina Yabe and Hanzawa, 1923

Polystomellina howchini (Chapman, Parr, and Collins)

Rotalia papillosa var. *compressiuscula* Howchin *(non* Brady), 1889, p. 15.

R. howchini Chapman, Parr, and Collins, 1934, p. 566, pl. ix, figs. 20 *a-c*. Howchin, 1936, p. 9.

Small examples of this species, which was described from the Lower Miocene of the Altona Bay Coal Shaft, near Melbourne, are common in the Upper Pliocene of the bore. It was also recorded from beds of similar age in the Cowandilla Bore by the senior author, who noted its wide distribution in the Australian Tertiaries. While it has hitherto been referred to the genus *Rotalia*, it appears to be a trochoid form related to *Elphidium* and is accordingly transferred to the genus *Polystomellina*.

Family PENEROPLIDAE

Genus Peneroplis Montfort, 1808

Peneroplis pertusus (Forskal)

(Pl. xvii, fig. 8)

Nautilus pertusus Forskal, 1775, p. 125, No. 65.

Peneroplis pertusus (Forskal): Brady, 1884, p. 204, pl. xiii, figs. 16, 17.

Examples of this widely-distributed species are common but are frequently badly eroded.

Genus Sorites Ehrenberg, 1840

Sorites marginalis (Lamarck)

(Pl. xvii, fig. 9)

Orbulites marginalis Lamarck, 1816, p. 196, No. 1.

Sorites marginalis (Lam.): Cushman, 1930, p. 49, pl. xviii, figs. 1-4.

This is known, for the most part, as a Recent form, inhabiting the shallow margins of warm seas. It is common in the Indo-Pacific region under such conditions, and is also known from the West Indies. Two specimens were obtained from the bore, the larger measuring 1·9 mm. in diameter.

Genus Amphisorus Ehrenberg, 1840

Amphisorus hemprichii Ehrenberg

(Pl. xix, fig. 7)

Amphisorus hemprichii Ehrenberg, 1838, Abhandl. K. Akad. Wiss., Berlin, p. 134, pl. iii, fig. 3. Cushman, 1930, p. 51, pl. xviii, figs. 5-7.

Orbitolites duplex Carpenter, 1883, p. 25, pl. iii, figs. 8-14; pl. iv, figs. 6-10; pl. v, figs. 1-13. Brady, 1884, p. 216, pl. xvi, fig. 7.

This species is better known as *Orbitolites duplex*, under which name it was described by Carpenter in his work on the *Orbitolites* of the "Challenger" Expedition. Cushman, however, after an examination of the types of *Amphisorus hemprichii* in the Ehrenberg collection in Berlin, considers that Carpenter's species is a synonym of the older form.

A. hemprichii occurs on the Great Barrier Reef and elsewhere in the warmer seas of the Indo-Pacific region, as well as in the Mediterranean and the West Indies. Two specimens, both very characteristic, have been obtained from the Upper Pliocene of the Adelaide Basin; the larger, from the Croydon Bore, has a diameter of 5 mm. The other is from the present bore. When these are mounted in fluid and examined by transmitted light, a clear distinction is seen between the single layer of chambers around the centre and the duplex arrangement of chambers in the latter portion of the shell.

Genus Marginopora Blainville, 1830

Marginopora vertebralis Blainville

Marginopora vertebralis Blainville, 1830, Dict. Sci. Nat., vol. lx, p. 377 (Quoy and Gaimard M.S.). Quoy and Gaimard, 1833, Voyage de l'Astrolabe, *fide* Blainville, 1834, Man. d'Actinologie, p. 412, pl. lxix, figs. 6, 6 *a-c*. Cushman, 1933, p. 67, pl. xix, figs. 11, 12.

Orbitolites complanata Carpenter *(non* Lamarck), 1883, p. 29, pl. v, figs. 14-18; pls. vi-viii. Brady, 1884, p. 218, pl. xvi, figs. 1-6; pl. xvii, figs. 1-6.

This species frequently occurs in great numbers in shallow water in the warmer parts of the Indo-Pacific, often attaining a large size. Its most southerly record appears to be that by Chapman and Parr (1935, p. 3) from the Great Australian Bight, off the coast of Western Australia. In the Lower and Upper Pliocene of South Australia it is a frequent fossil. In the present bore material fragments occur in the fine sand, and in one of the sandy nodules which occur in the "white sand" horizon, an impression measuring 20 mm. in diameter was seen.

Family ROTALIIDAE

Genus Discorbis Lamarck, 1804

Discorbis globularis (d'Orbigny)

(Pl. xvii, fig. 10)

Rosalina globularis d'Orbigny, 1826, p. 271, pl. xiii, figs. 1, 2; Modèles, No. 69.
Discorbis globularis (d'Orb.): Chapman, Parr, and Collins, 1934, p. 562, pl. viii, figs. 7 *a-c*.

There is a small example which measures 0·55 mm. in diameter. It is intermediate between the typical form of this species and *Discorbis australis* Parr, which has heavily limbate sutures. It also bears some resemblance to *Tretomphalus concinnus* (Brady), when the balloon chamber of the latter is missing. *T. concinnus* attains a diameter of 0·25 mm. only and the shell is very thin and transparent, with the perforations much smaller and less conspicuous than those of *D. globularis*.

Discorbis dimidiatus (Jones and Parker)

Discorbina dimidiata Jones and Parker, 1862, p. 201, text fig. 32 *b*.
Discorbis vesicularis (Lamarck) var. *dimidiata* (J. & P.): Parr, 1932, p. 227, pl. xxi, figs. 27-29.

This species has been dealt with at length by the junior author *(loc. cit.)* in 1932 as a variety of the European Eocene *D. vesicularis*. He now considers that the Australian form should be given specific rank, and it is here treated accordingly.

D. dimidiatus is perhaps the most distinctive foraminifer occurring in shallow water on the southern coast of Australia reaching its finest development in Gulf St. Vincent. In the present bore a few examples were found, one measuring 1·2 mm. The species also occurs in the Lower Pliocene of the Muddy Creek area, near Hamilton, Victoria.

Discorbis cycloclypeus sp. nov.

(Pl. xvi, fig. 11; pl. xviii, figs. 5, 12; pl. xix, fig. 13)

Description—Test trochoid, almost circular in outline, biconvex, the central portion of the superior face dome-shaped and surrounded by a flattened border, inferior surface only slightly convex; periphery subacute; chambers 10 to 11 in the last-formed whorl, increasing gradually in size as added, not inflated; sutures on dorsal side barely visible unless the shell is moistened, oblique, flush, gently recurved on the ventral side and very much depressed; wall smooth and not distinctly perforated in the earlier whorls, coarsely perforated in the last-formed whorl; wall thickened at the centre of the inferior face; aperture an arched slit at the base of the last-formed chamber. Diameter up to 1·5 mm., height to 1 mm.

Holotype in Howchin Collection, South Australian Museum.

This species is one of the *D. vesicularis* group and appears to be quite distinct from any previously described form. It connects *D. balcombensis* Chapman, Parr, and Collins, from the Miocene of Victoria, with *D. dimidiatus* var. *acervulinoides* Parr, from Gulf St. Vincent, but has consistently a larger number of chambers to the whorl than these two species. It may also be distinguished from *D. balcombensis* by its strongly-depressed sutures on the ventral side, and from the other form by the shape of the upper side of the shell, which recalls a rounded, convex shield, thickened in the centre. Examples are fairly common in the Upper Pliocene of the Abattoirs Bore and the species also occurs in the Lower Pliocene of the Muddy Creek area, in Victoria.

Genus Rotalia Lamarck, 1804

Rotalia beccarii (Linné)

Nautilus beccarii Linné, 1767, p. 1,162; 1788, p. 3,370.
Rotalia beccarii (Linné): Cushman, 1931, p. 58, pl. xii, figs. 1-7; pl. xiii, figs. 1, 2.

This is the commonest foraminifer in the Upper Pliocene of the bore, several hundred examples having been obtained. The largest is 2·5 mm. in diameter.

Genus Epistomaria Galloway, 1933

(?) Epistomaria polystomelloides (Parker and Jones)

(Pl. xvii, figs. 5-7, 11-13)

Discorbina polystomelloides Parker and Jones, 1865, p. 421, pl. xix, figs. 8 *a-c*. Brady, 1884, p. 652, pl. xci, figs. 1 *a-c*. Heron-Allen and Earland, 1915, p. 698, pl. lii, figs. 19-23.

This rarely recorded species was originally described from "Australian coral reefs," and, with the exception of some fossil specimens attributed to it by Heron-Allen and Earland from Selsey Bill, Sussex, England, it appears to be confined to the warmer parts of the Indian and south-western Pacific Oceans and the late Tertiary of Australia. It is here doubtfully referred to Galloway's genus *Epistomaria*, the genotype of which is *Discorbina rimosa* Parker and Jones. The characters of this genus are defined by Cushman in the second edition of his book, "Foraminifera. Their Classification and Economic Use" (1933, p. 240), as follows: "Test trochoid, dorsal side with regular chambers, ventral side with supplementary chambers or alar projections toward the umbilicus, which is covered; wall calcareous, finely perforate; apertures ventrally at the periphery of the secondary chambers, with supplementary apertures dorsally at inner edge of chamber along the suture between it and the preceding chamber, narrow, elongate." These do not accord with the structure of the present species, which has been worked out by Heron-Allen and Earland (1915, p. 698) in their Kerimba Monograph. The junior author, who has devoted a considerable amount of time to the investigation of the position of the species, is inclined to the opinion that it represents a new generic type, but, pending the examination of the type specimen of *Discorbina rimosa,* this cannot at present be decided.

Eight examples of this form were met with in the Abattoirs Bore material, and it occurs also in beds of similar age in the Glanville Bore. There is one very large specimen from the Glanville Bore measuring 4 mm. across, the whole of the shell wall being extremely thick and with the surface largely covered by undulose ridges of imperforate shell material (pl. xvii, figs. 5, 6). Those from the Abattoirs Bore are typical except one or two which are similar to *Discorbis dimidiatus,* except that they have the second aperture in the septal face, which is a feature of the present species (pl. xvii, figs. 11, 12).

Family ANOMALINIDAE

Genus Cibicides Montfort, 1808

Cibicides lobatulus (Walker and Jacob)

Nautilus lobatulus Walker and Jacob, 1798, p. 642, pl. xiv, fig. 36.
Cibicides lobatulus (W. & J.): Cushman, 1931, p. 118, pl. xxi, figs. 3 *a-c.*

This common species is rare in the bore samples.

Family PLANORBULINIDAE

Genus Gypsina Carter, 1877

Gypsina globulus (Reuss)

Ceriopora globulus Reuss, 1847, Haidinger's Naturw. Abhandl., vol. ii, p. 33, pl. v, fig. 7.
Gypsina globulus (Reuss): Brady, 1884, p. 717, pl. ci., fig. 8.

There is one example. This species occurs in Australia in deposits from Miocene to Recent.

PART II MIOCENE SPECIES

Note—Material of Miocene age was examined by Professor Howchin from the depths specified below, and lists of the foraminifera identified prepared by him. As the specimens on which the identifications were based, with the exception of those species dealt with later in the systematic portion, have not been located in the Howchin Collection, it has been deemed advisable to give the lists as Professor Howchin left them, with such alterations as are necessary to bring them into line with present nomenclature. This course is followed in preference to omitting all reference to the species which have not been seen, so that a better idea of the foraminiferal assemblage at each of the depths mentioned may be obtained.—W. J. P.

575-620 Feet

The matrix is a light-coloured calcareous sandstone with a limited number of bryozoa.

Species Identified—

Textularia sagittula Defrance	
Quinqueloculina agglutinans d'Orb. - - -	5 specimens
Q. venusta Karrer - - - - - -	Rather scarce
Q. adelaidensis sp. nov. - - - - -	2 specimens
Spiroloculina (?) **lapidigera** sp. nov. - - -	1 specimen
Triloculina trigonula (Lamarck) - - -	1 do.
T. circularis Bornemann - - - - -	Very rare
Dentalina obliqua (Linné)	
Guttulina problema d'Orb. - - - -	2 examples
G. irregularis (d'Orb.) - - - - -	1 specimen
Globulina gibba d'Orb.	
Sigmomorphina subregularis sp. nov. - -	6 specimens
Sigmoidella elegantissima (P. & J.) - - -	Common
S. kagaensis C. & O. - - - - -	Common
Elphidium adelaidense sp. nov.	
E. chapmani Cushman - - - - -	Frequent
E. sp. nov. - - - - - - -	1 specimen
(?) **Operculina umbonifera** sp. nov.	
Discorbis sp. cf. *vesicularis* (Lam.)	
D. cycloclypeus sp. nov.	
Miniacina miniacea (Pallas)	

710-775 Feet

Species Identified—

Textularia agglutinans d'Orb. - - - -	Rather scarce
Gaudryina rugosa d'Orb	
Pyrgo sp.	
Dentalina obliqua (Linné) - - - -	Rare
D. soluta Reuss - - - - - - -	Very rare
Lenticulina rotulata (Lam.) - - - -	Rare
Robulus cultratus (Montfort) - - - -	Rare
Guttulina problema d'Orb. - - - - -	Rare
Sigmoidella elegantissima (P. & J.) - - -	Moderately common
Nonion depressulus (W. & J.) - - - -	Rather scarce
Elphidium crispum (Linné) - - - -	Small and rather scarce
E. craticulatum (F. & M.) - - - - -	Small and rare
Operculina victoriensis C. & P. - - - -	Very common
Rotalia verriculata sp. nov. - - - -	Very common
Epistomina elegans (d'Orb.) - - - -	Small, rather scarce
Amphistegina haucrina d'Orb. - - - -	Rather scarce

Planorbulina mediterranensis d'Orb. - - -	Rather scarce
Gypsina vesicularis (P. & J.) - - - -	Rather scarce
G. howchini Chapman	
Planorbulinella plana (H. - A. & E.)	

800-820 Feet

Species Identified—

Textularia agglutinans d'Orb., var. *porrecta* Brady	Rare
T. gramen d'Orb.	
T. concava (Karrer) - - - - - -	1 specimen
Gaudryina (Siphogaudryina) victoriana Cushm.	4 specimens
Dorothia parri Cushman - - - - -	Rare
Quinqueloculina venusta Karrer	
Pyrgo depressa (d'Orb.)	
Dentalina obliqua (Linné) - - - -	2 large specimens
D. obliquestriata Reuss - - - - -	Rare
Sigmoidella elegantissima (P. & J.) - - -	Moderately common
Operculina victoriensis C. & P. - - - -	Rather scarce
Gyroidina soldanii d'Orb. - - - -	rare
Rotalia verriculata sp. nov. - - - -	Very common and large
Globigerina bulloides d'Orb. - - - -	1 example
Cibicides lobatulus (W. &. J.)	
Gypsina vesicularis (P. & J.) - - - -	Rather scarce
G. howchini Chapman - - - - -	do.
G. globulus (Reuss) - - - - - -	do.
Miniacina minuta (Chapman) - - - -	Rare

Family LAGENIDAE

Genus Dentalina d'Orbigny, 1826

Dentalina obliqua (Linné)

(Pl. xvi, fig. 5)

For references, see this species under Part I.

There is one large example measuring 4·5 mm. in length. Similar specimens are common in the Miocene of Victoria.

Dentalina sp. cf. vertebralis (Batsch)

(Pl. xvi, figs. 6, 7)

There are four specimens, one curved (pl. xvi, fig. 6) and three straight, which may belong to this species. Batsch's type-figure (*vide* Cushman, Contr. Cushman Lab., vol. vii, pt. 3, 1931, pl. viii, fig. 20, where it is reproduced) represents a broken specimen, almost straight, and increasing rather quickly in diameter, with fairly numerous costae which are continued throughout the length of the test. Cushman's second figure (in the same work) of an example from the type locality, Rimini, on the Adriatic, shows another straight shell, with well-defined suture lines of clear shell material and only about eight costae. The dentaline specimen we figure is, in the earlier portion of the shell, fairly close to Cushman's second figure, but additional costae are developed in the latter portion. The three nodosarian examples are short, with a maximum of six chambers, and the number of costae is respectively 8, 12, and 16. The sutures are somewhat depressed.

Genus Frondicularia Defrance, 1826

Frondicularia lorifera Chapman
(Pl. xvi, fig. 4)

Frondicularia lorifera Chapman, 1913, p. 171, pl. xvi, fig. 6.

One typical example was found. This very distinct species was described from the Miocene of the Mallee bores in Victoria and does not appear to have been since recorded. The junior author has, however, specimens from the Lower Beds at Muddy Creek and from Neumerella and Torquay, all in the Miocene of Victoria. The shell varies considerably in outline. Normally it is lanceolate, but may be rhomboid or spatulate. The surface is flat and occasionally depressed along the median line. The most characteristic features are the thick shell-wall and the exceptionally heavy, raised, strap-like layers of clear material on the suture lines. The proloculus bears, on each side of the test, two raised costae of similar material.

Family POLYMORPHINIDAE

Genus Pseudopolymorphina Cushman and Ozawa, 1928

Pseudopolymorphina rutila (Cushman) var. parri Cushman and Ozawa
(Pl. xvii, fig. 14)

Pseudopolymorphina rutila (Cushman) var. *parri* Cushman and Ozawa, 1930, p. 100. Parr and Collins, 1937, p. 201, pl. xiv, figs. 4 *a-c*.

This species has hitherto been known only from the Miocene of Rocky Point, Torquay, Victoria, where is was collected by the junior author, so it is noteworthy that a typical example has been found in the Miocene of the Abattoirs Bore.

Genus Polymorphina d'Orbigny, 1826

Polymorphina myrae Parr and Collins
(Pl. xvi, figs. 9, 10)

Polymorphina myrae Parr and Collins, 1937, p. 203, pl. xv, figs. 4 *a-c*.

The presence of this species in the Miocene of the bore calls for special remark for, as far as we are aware, it does not occur elsewhere in beds older than the Lower Pliocene. The types were from the Upper Beds at Beaumaris, Victoria, to which it has previously been confined. There are two specimens from the bore, one, which is immature and with the initial end bearing a short spine (pl. xvi, fig. 10), and another which is a mature, typical example measuring 2·35 mm. in length (pl. xvi, fig. 9).

Genus Sigmomorphina Cushman and Ozawa, 1928

Sigmomorphina subregularis sp. nov.

(Pl. xviii, figs. 2, 11)

Description—Test comparatively large, oval or sub-rhomboidal, about $1\frac{1}{2}$ times as long as wide, and thickness half the width; a median sigmoidal longitudinal ridge on both sides, margin of shell subacute; chambers numbering about 16 in the adult, compressed, long, arranged in a clockwise sigmoid series, each chamber removed much farther from the base, those on the right hand side with a pronounced median ridge; sutures on the right hand side of the median line of the shell much depressed, on the left hand side slightly depressed; wall smooth and comparatively thick; aperture radiate. Length of holotype, 2·55 mm.; width, 1·5 mm.; thickness, 0·78 mm.

Holotype in Howchin Collection, South Australian Museum.

This very distinct species is represented by six examples. It may be compared with *S. pseudoregularis* Cushman and Thomas (1929, Journ. Pal., vol. iii, p. 178, pl. xxiii, figs. 5 *a–c*), from the Eocene of Texas, U.S.A. This is one-third of the size of the present species; while the shell has a similar median fold, the chambers are arranged in an anti-clockwise sigmoid series and the centre of each chamber on the right hand side of the shell is not ridged.

Family NONIONIDAE

Genus Nonion Montfort, 1808

Nonion novozealandicus Cushman

(Pl. xviii, fig. 15)

Nonion novozealandicum Cushman, 1936, (1), p. 66, pl. xii, figs. 6 *a, b*.

The types of this species were from the Upper Oligocene of Motutara Point, Kawhia Harbour, New Zealand. One typical example, 0·90 in length, was found in the bore material.

Genus Elphidium Montfort, 1808

Elphidium sp. cf. **adelaidense** sp. nov.

(Pl. xvii, fig. 3)

There is one specimen which may belong to this species which we have described from the Upper Pliocene of the bore. It is more compressed than those from higher in the bore.

Elphidium chapmani Cushman

Elphidium chapmani Cushman, 1936 (2), p. 80, pl. xiv, figs. 6 *a, b*.

Four examples were found. They measure about 1·2 mm. in diameter and otherwise agree with Cushman's description and figures, except that the edge of the test is slightly keeled. The species was described from material forwarded to the author by Parr from the Miocene of Neumerella, near Orbost, Victoria.

Elphidium sp.
(Pl. xviii, fig. 8)

The figure represents a unique example of what is probably a new species. The test is stout and umbonate, the thickness being one-half of the diameter in side view. There are 16 chambers in the outside whorl; these are of nearly uniform size and shape and are slightly inflated. The sutures are rather indistinct and depressed. The chamber walls are covered closely with raised cross bars of shell material parallel to the periphery and, with the beads on the umbones, giving an ornate appearance to the test. The diameter is 1·2 mm., and the thickness 0·6 mm In the absence of further material, it has been deemed inadvisable to make a specific determination.

Family CAMERINIDAE

Genus Operculina d'Orbigny, 1826

(?) **Operculina umbonifera** sp. nov.
(Pl. xviii, figs. 3, 4, 6, 13, 14)

Description—Test a little longer than broad, slightly asymmetrical, periphery rounded or subacute, rarely faintly lobulated in the last two or three chambers, the central half of each side of the shell strongly umbonate, the umbo composed of laminated shell material, finely perforate; whorls numbering usually three, each whorl added obliquely so that the axis of the test in vertical section is curved; 12 to 13 chambers in the last-formed whorl, of uniform shape, increasing slightly in size as added; sutures indistinct or invisible, very slightly recurved; wall thick, laminated, closely and distinctly perforate in sections of the shell; canal system present but weakly developed, apparently consisting of interseptal canals and a few tubular passages in the "marginal cord" in the plane of coiling; aperture a narrow, curved slit placed a little to one side at the base of the triangular face and next the preceding coil. Length of holotype, 1·3 mm.; breadth, 1·1 mm.; thickness, 0·75 mm.

Holotype in Howchin Collection, South Australian Museum.

It is difficult to place this species satisfactorily with the material available. There can be little doubt that its affinities are with the Camerinidae, near the genus *Operculina*, but the test of this genus and of related genera is invariably bilaterally symmetrical. Possibly we have a new generic type, but, as there are only five specimens, three of which have been used to make sections, further specimens are required before the position of the species can be satisfactorily ascertained.

Operculina victoriensis Chapman and Parr
(Pl. xviii, fig. 10)

Operculina victoriensis Chapman and Parr, 1938, p. 284, pl. xvi, figs. 3-8; text fig. 2.

This species, which has just been described from the Miocene of Victoria, is represented by three typical specimens, the largest of which measures 2·3 mm. Its range in Victoria is from the Lower to the Middle Miocene.

Family ROTALIIDAE

Genus Rotalia Lamarck, 1804

Rotalia verriculata sp. nov.

(Pl. xix, figs. 8, 9, 11, 15)

Rotalina calcar Chapman (*non Calcarina calcar* d'Orbigny), 1910, p. 289, pl. liii, fig. 2.

Rotalia calcar Heron-Allen and Earland (*non Calcarina calcar* d'Orb.), 1924, p. 180.

Calcarina defrancii Heron-Allen and Earland (*non* d'Orbigny), 1924, p. 182.

Description—Test trochoid, plano-convex to biconvex, the ventral side always the more convex, periphery lobulate, broadly rounded to subacute, sometimes with irregular spinose projections on the later chambers, umbilical area with a coarsely-beaded plug or closed and bearing one large rounded bead of shell material; chambers usually 12 or 13 in the last-formed whorl, increasing gradually in size as added, strongly inflated on the ventral side, only the later chambers well inflated on the dorsal side; sutures much depressed on the ventral side and frequently in the last quarter of the outside whorl on the dorsal side, slightly recurved on both faces; wall thick, closely covered on the ventral side with an ornament of raised cross bars parallel to the periphery and sometimes numerous large raised beads in the centre of the test and along the median line of the earlier chambers, dorsal side thickly studded and at times completely covered with tubercles of exogenous shell-growth; septa double; aperture an elongate slit at the inner margin of the ventral side of the last chamber. Diameter up to 2·8 mm.; height, to 1 mm.

Holotype in Howchin Collection, South Australian Museum.

This species is very common in the Lower Miocene limestone of the Filter and New Quarries at Batesford, Victoria, and occurs elsewhere in Victoria in beds of a similar facies and age. Chapman (*loc. supra cit.*), in his paper "A Study of the Batesford Limestone," has given photographs of four specimens which illustrate well the variations found in the species, particularly in the gradual loss of the umbilical plug. The specimens from the Abattoirs Bore also show the transition from a form with a solid umbilical plug to one in which it is absent. Heron-Allen and Earland have referred their Batesford specimens to two species, those with a strongly biconvex test, solid umbilical stud and projecting spinous processes to *Rotalia calcar*, and those with a plano-convex test, almost devoid of spinous processes, and studded all over with beads of exogenous shell-growth to *Calcarina defrancii*. From our material, however, it appears that none of the features on which these authors have relied for their identification of the two forms is constant, as, apart from the presence or absence of the umbilical plug, the *R. calcar* form is frequently almost plano-convex and more often than not without any peripheral spines, while the *C. defrancii* form may have a biconvex test with peripheral spines (*vide* pl. xix, figs. 8, 9 and 15, and also Chapman's bottom left-hand figure). Reference to the original figures of *Calcarina calcar* and *C. defrancii* and also *C. gaimardii* d'Orb., with which Heron-Allen and Earland compared the present species, will show that the latter is quite distinct. It appears to be confined to the lower part of the Miocene of Victoria and South Australia.

Family AMPHISTEGINIDAE

Genus Amphistegina d'Orbigny, 1826

Amphistegina hauerina d'Orbigny

(Pl. xviii, fig. 1)

Amphistegina hauerina d'Orbigny, 1846, p. 207, pl. xii, figs. 3-5.
A. lessonii Chapman *(non* d'Orbigny*)*, 1910, p. 294, pl. liii, fig. 6. Chapman and Crespin, 1932, fig. 3.

This compressed, lenticular form of *Amphistegina* was described from the Miocene of the Vienna Basin. Typical examples occur in the bore, and it is frequently very common in the Lower and Middle Miocene of Victoria.

Family CHILOSTOMELLIDAE

Genus Sphaeroidina d'Orbigny, 1826

Sphaeroidina bulloides d'Orbigny

(Pl. xviii, fig. 9)

Sphaeroidina bulloides d'Orbigny, 1826, p. 267, No. 1; Modèles, No. 65. Brady, 1884, p. 620, pl. lxxxiv, figs. 1-7.

There is one example 1·3 mm. in diameter.

Family PLANORBULINIDAE

Genus Planorbulina d'Orbigny, 1826

Planorbulina mediterranensis d'Orbigny

(Pl. xix, fig. 12)

Planorbulina mediterranensis d'Orbigny, 1826, p. 280, pl. xiv, figs. 4-6; Modèles, No. 79. Brady, 1884, p. 656, pl. xcii, figs. 1-3.

There are two examples. This species was recorded by Heron-Allen and Earland (1924, p. 173) from the Lower Miocene of Batesford, Victoria.

Genus Planorbulinella Cushman, 1927

Planorbulinella inaequilateralis (Heron-Allen and Earland)

(Pl. xix, fig. 2)

Planorbulina larvata Parker and Jones var. *inaequilateralis* Heron-Allen and Earland, 1924, p. 174, pl. xii, figs. 85-90.
Planorbulinella inaequilateralis (H.-A. & E.): Crespin, 1936, pl. i, fig. 6.

There are two specimens, the larger measuring 1·4 mm. in diameter. This form was described from the Lower Miocene of Batesford, Victoria, as a variety of *Planorbulina larvata* characterised by a convex superior surface and a concave inferior side. Heron-Allen and Earland also recorded *P. larvata* in the same paper, this representing the flat form of *inaequilateralis*. We agree, however, with Miss I. Crespin, B.A., the Commonwealth Palaeontologist, that *P. larvata* does not occur in the Tertiary of Victoria and that the variety *inaequilateralis* should, therefore, be given the status of a species. In *P. larvata* the chambers in the outside ring are separated from one another by the chambers of the preceding ring, while in *P. inaequilateralis* they are contiguous.

The present species has not been found outside the Lower Miocene of Victoria and South Australia.

Genus GYPSINA Carter, 1877

Gypsina globulus (Reuss)

(Pl. xviii, fig. 16)

For references see this species under Part I.

One specimen was found. This widely distributed species is common in the Lower Miocene of Batesford (*vide* Heron-Allen and Earland, 1924, p. 183, pl. xiv, figs. 117, 118).

Gypsina howchini Chapman

Gypsina howchini Chapman, 1910, p. 291, pl. lii, figs. 4 *a, b;* pl. liii, figs. 3-5. Heron-Allen and Earland, 1924, p. 183. Crespin, 1936, pl. i, fig. 8, ? fig. 7.

Miss Crespin's fig. 8, which represents an example from the type locality, Batesford, shows the surface features of this species very well. The test is discoidal and the faces are slightly convex in the smaller specimens becoming flat or slightly concave in the larger examples. The surface of the small specimens is sometimes pustular, but typically the chamber surfaces are flat and surrounded by a raised limbate margin to each chamber. These margins form a reticulate surface to the test, the intervening areas being coarsely perforate.

G. howchini has hitherto been known only from the Lower Miocene of Victoria, so it is interesting to meet with a large typical example in the Abattoirs Bore. This is 2·7 mm. in diameter.

Family RUPERTIIDAE

Genus Carpenteria Gray, 1858

Carpenteria rotaliformis Chapman and Crespin

(Pl. xix, figs. 3, 4)

Carpenteria proteiformis Goës: Chapman *(pars)*, 1913, p. 171, pl. xvi, fig. 7.
C. rotaliformis Chapman and Crespin, 1930, p. 98, pl. v, figs. 7, 8. Chapman, Parr, and Collins, 1934, p. 572, pl. xi, figs. 44 *a-c*.

Two typical examples were found in the bore material. This very distinct species was described from the Lower Miocene of Victoria, in which it is widely distributed. The present record is the first from outside Victoria.

Family HOMOTREMIDAE

Genus Miniacina Galloway, 1933

Miniacina minuta (Chapman)

(Pl. xix, fig. 10)

Polytrema minutum Chapman, 1910, p. 292, pl. lii, figs. 3 *a, b*. Heron-Allen and Earland, 1924, p. 184.

There are three typical specimens of this species, which was described from the Lower Miocene of Batesford, Victoria, and occurs elsewhere in beds of the same age in Victoria.

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EXPLANATION OF PLATES

(Except where otherwise stated, the specimens figured are from the Abattoirs Bore.)

PLATE XV

Fig. 1 ? *Quinqueloculina agglutinans* d'Orb. (immature example). Upper Pliocene, 341-500ft. x 31

Fig. 2 *Nubecularia lucifuga* Defrance, var. *lapidea* Wiesner Upper Pliocene, 341-500 ft. x 17

Figs. 3, 4 *Quinqueloculina ammophila* Parr. Back view. Upper Pliocene, 341-500 ft. x 28

Figs. 5, 7 **Q. adelaidensis** sp. nov. 5, Holotype, front view; 7, apertural view of another specimen. Upper Pliocene, 341-500 ft. 5, x 41; 7, x 61

Fig. 6 *Pyrgo* sp. cf. *bulloides* (d'Orb). Upper Pliocene, 341-500 ft. x 19

Figs. 8, 9 *Hauerina ornatissima* (Karrer). 8, Upper Pliocene, Cowandilla Bore. x 43. 9, Upper Pliocene, Abattoirs Bore, 341-500 ft. x 41

Fig. 10 **Spiroloculina lapidigera** sp. nov. Holotype, side view. Upper Pliocene, Cowandilla Bore, 420 ft. x 20

Figs. 11-13 *Flintina triquetra* (Brady) 11, side view; 12, section; 13, edge view. Upper Pliocene, 341-500 ft. 11, 12, x 11; 13, x 25

Figs. 14 *a*, *b* **Nodobaculariella cultrata** sp. nov. Holotype. *a*, side view; *b*, apertural view. Upper Pliocene, 341-500 ft. x 34

Fig. 15 *Quinqueloculina bosciana* d'Orb. Upper Pliocene, 341-500 ft. x 46

PLATE XVI

Figs. 1-3 *Nubecularia lucifuga* Defrance, var. *lapidea* Wiesner. Upper Pliocene, Croydon Bore, 400-410 ft. 1, 2, x 16; 3, x 12

Fig. 4 *Frondicularia lorifera* Chapman. Lower Miocene, 710-775 ft. x 19

Fig. 5 *Dentalina obliqua* (Linné). Lower Miocene, 710-820 ft. x 19

Figs. 6, 7 *D.* sp. cf. *vertebralis* (Batsch). Lower Miocene, 710-775 ft. 6, x 17; 7, x 27

Fig. 8 Foraminifer indet. (? *Valvulina* sp.). Lower Miocene, 710-820 ft. x 19

Figs. 9, 10 *Polymorphina myrae* Parr and Collins. Lower Miocene, 710-775 ft. 9, x 25; 10, x 18

Fig. 11 **Discorbis cycloclypeus** sp. nov. Holotype, basal view. Upper Pliocene, Cowandilla Bore. x 14

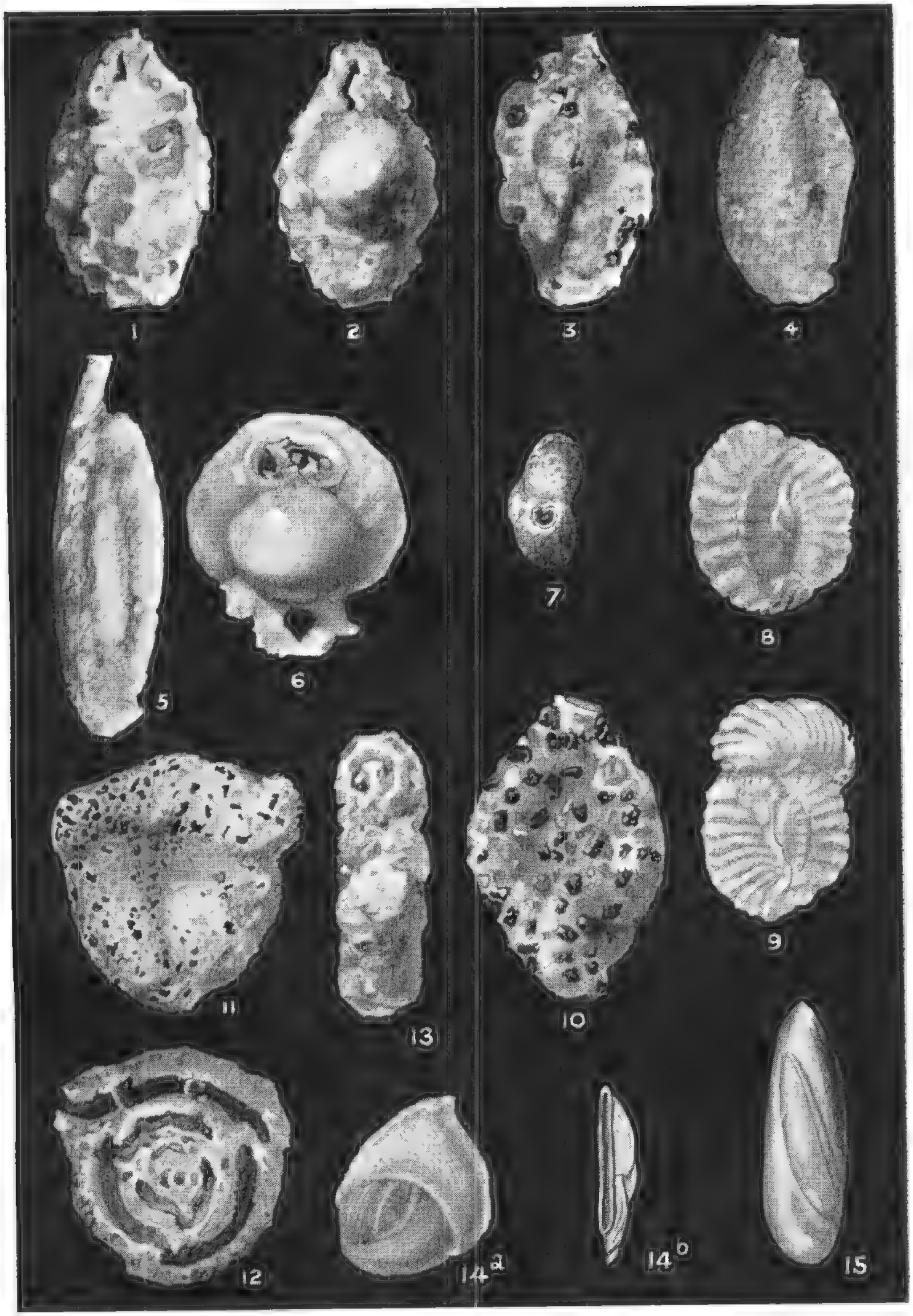
Fig. 12 *Clavulina multicamerata* Chapman. A very slender example. Upper Pliocene, 341-500 ft. x 32

Fig. 13 *Valvulina* sp. cf. *triangularis* d'Orb. Tertiary. At head of Hallett's Cove, S. Aust. x 15 (This figure has been inadvertently included on the plate.)

Fig. 14 *Quinqueloculina polygona* d'Orb. Upper Pliocene, 341-500 ft. x 29

PLATE XVII

Figs. 1, 2, 4 **Elphidium rotatum** sp. nov. 1, Side view of holotype. x 20. 2, Portion of outer surface of holotype, showing nature of ornament. x 110. 4, Edge view of another example. x 20. All from Kingston, S. Aust.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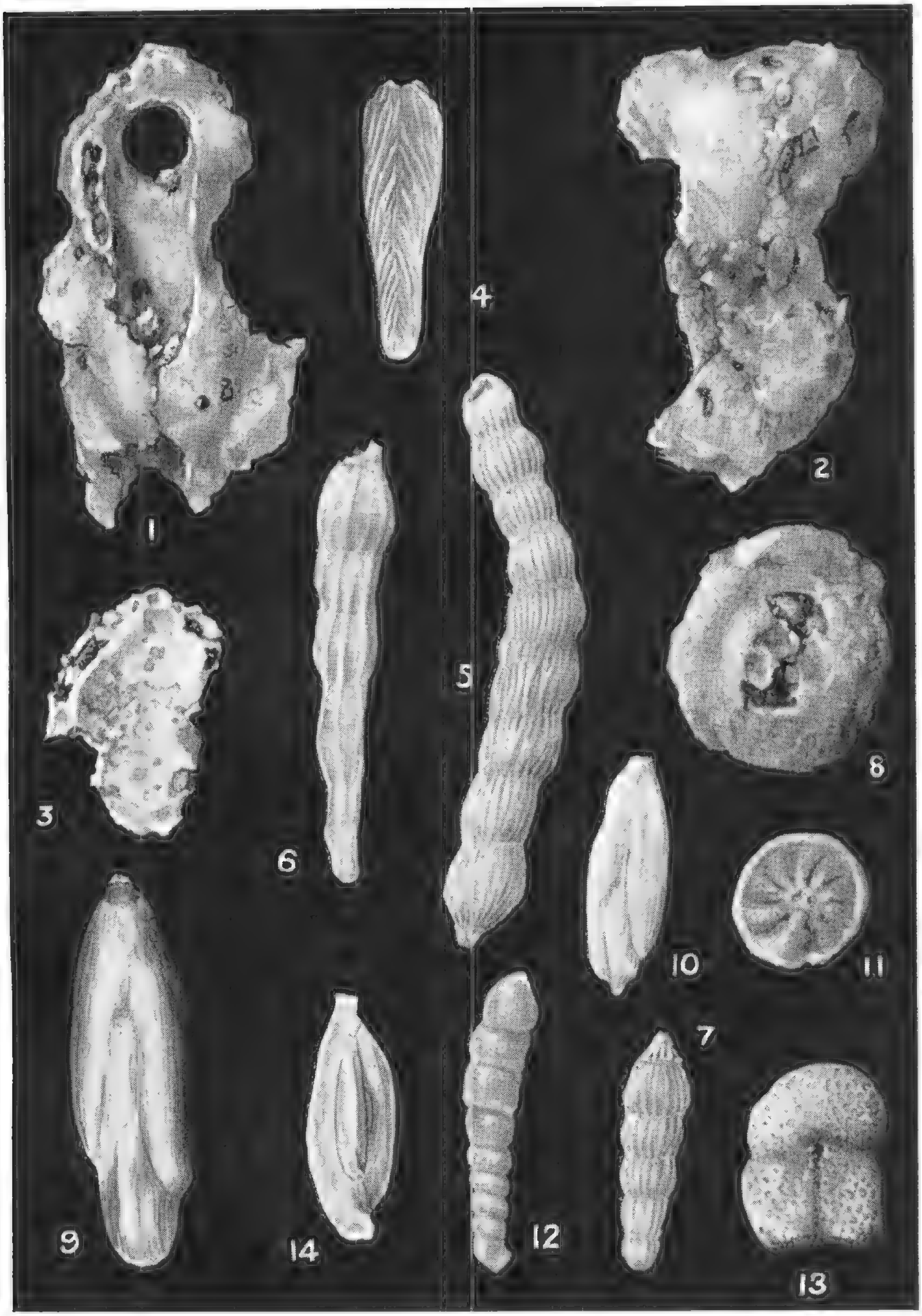
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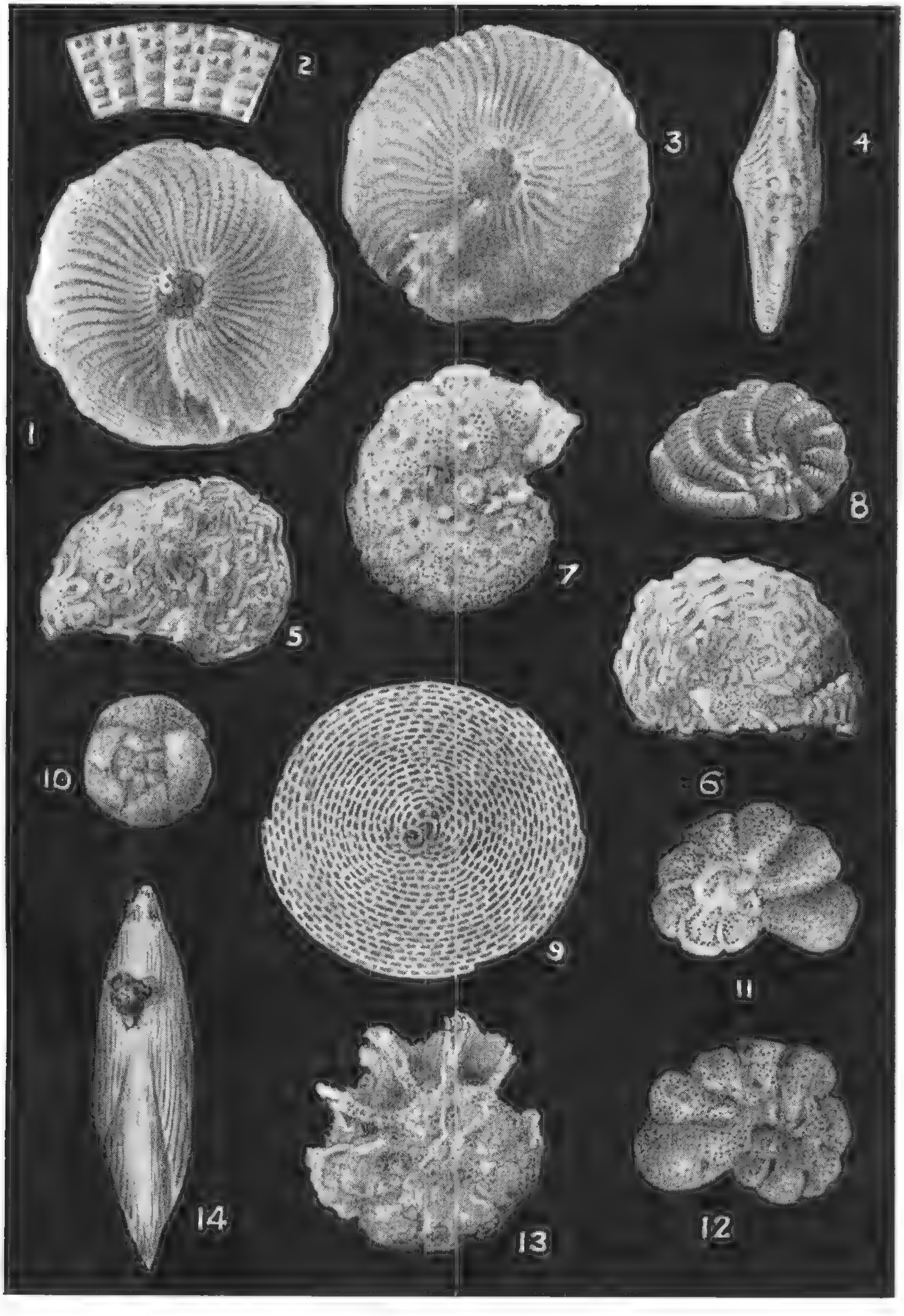
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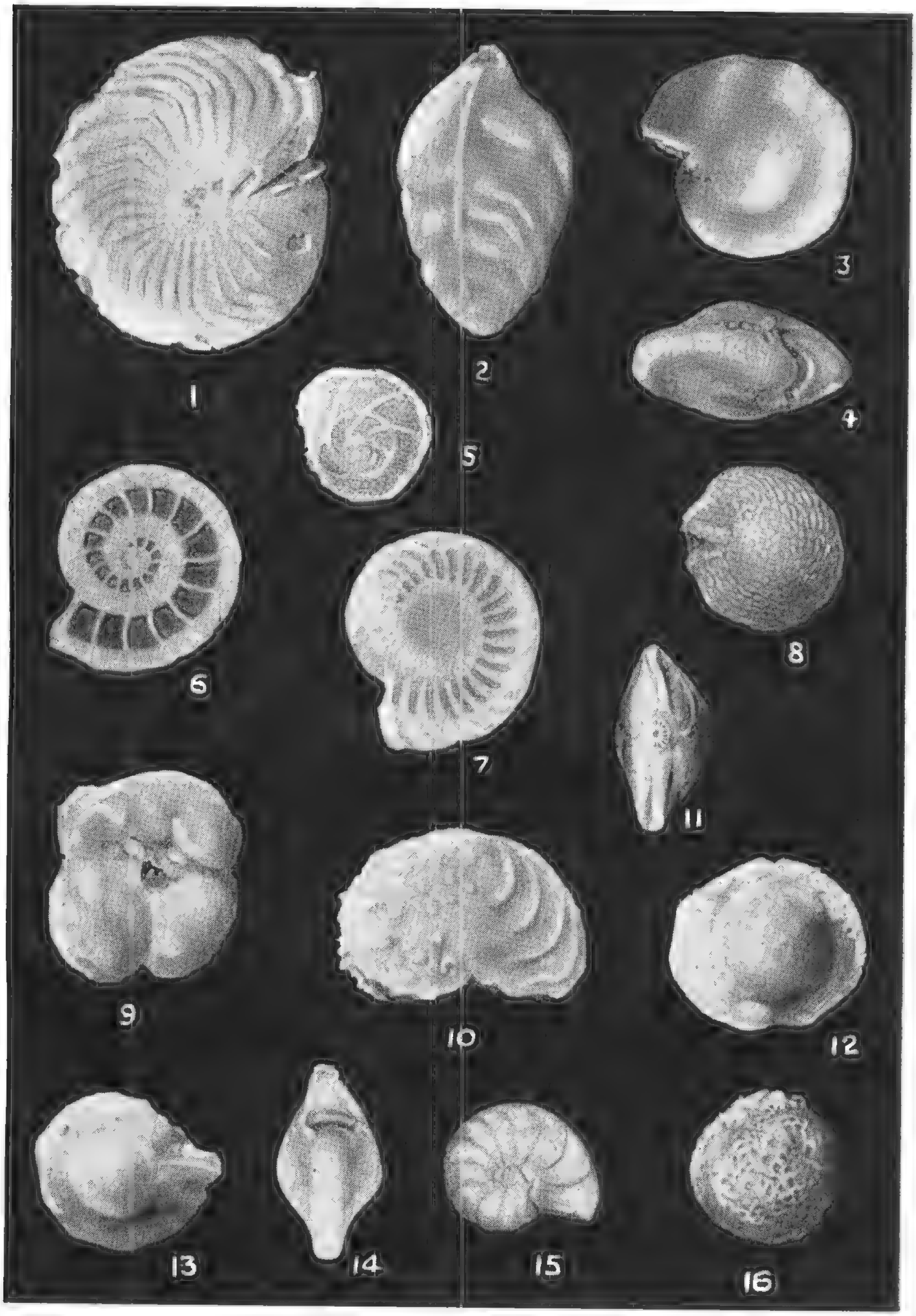
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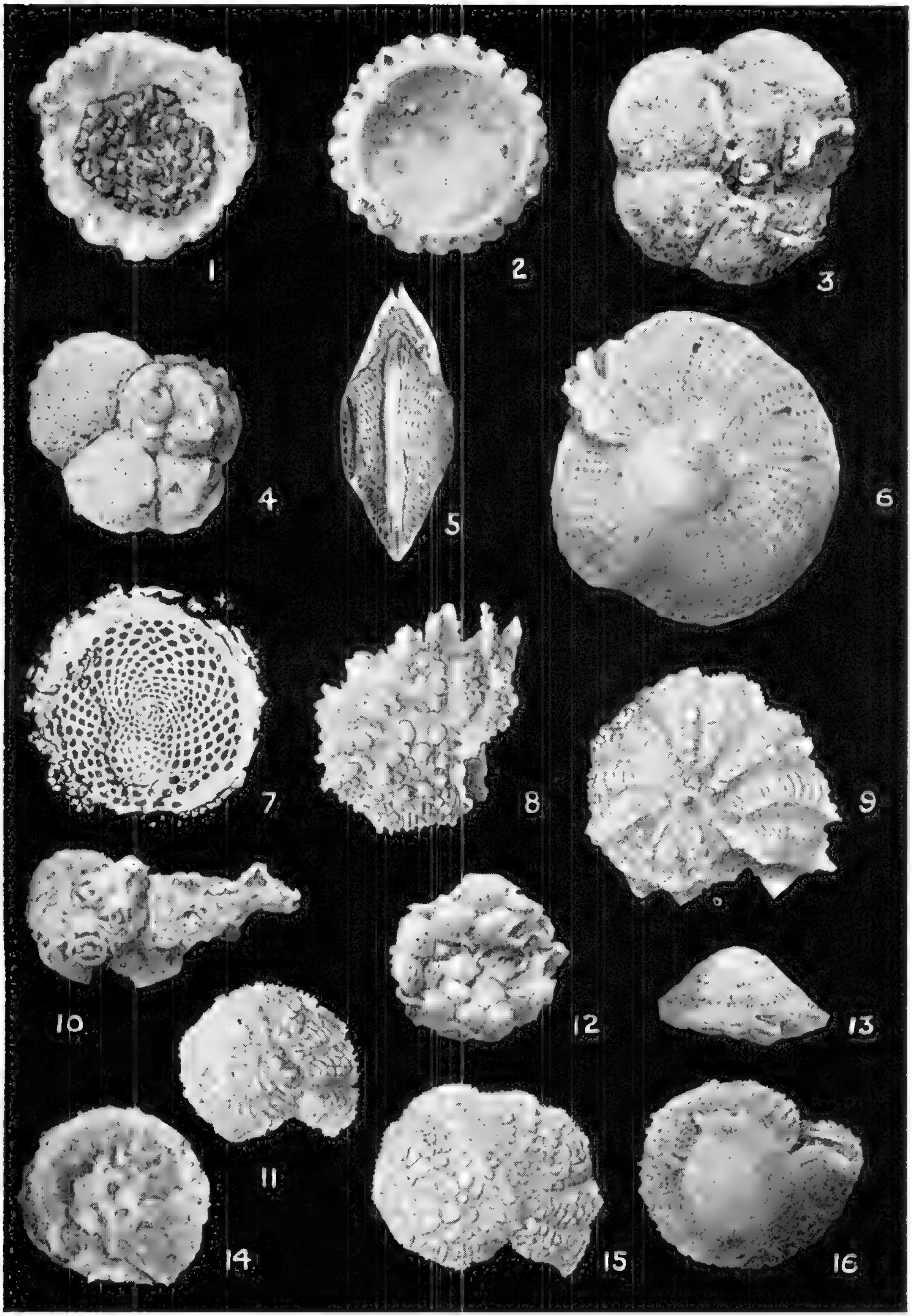
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Fig. 3 **E.** sp. cf. **adelaidense** sp. nov. Miocene, 590-620 ft. x 16

Figs. 5-7, 11-13 (?) *Epistomaria polystomelloides* (Parker and Jones). 5, 6, Opposite sides of specimen from Upper Pliocene, Glanville Bore, 385 ft. x 9. 7, Upper Pliocene, Glanville Bore, 480⅔-485 ft. x 13. 11, Upper Pliocene, Cowandilla Bore, 470-485 ft. x 20 12, Another weakly-developed specimen from Upper Pliocene, Abattoirs Bore, 341-500 ft. x 21. 13, a worn, typical example from Abattoirs Bore, 341-500 ft., showing the double septa. x 13

Fig. 8 *Peneroplis pertusus* (Forskal). Upper Pliocene, 341-500 ft. x 32

Fig. 9 *Sorites marginalis* (Lamarck). Upper Pliocene, 341-500 ft. x 23

Fig. 10 *Discorbis globularis* (d'Orb.). Upper Pliocene, 341-500 ft. x 27

Fig. 14 *Pseudopolymorphina rutila* (Cushman), var. *parri* Cushman and Ozawa. Lower Miocene, 710-820 ft. x 26

Plate XVIII

Fig. 1 *Amphistegina hauerina* d'Orb. Lower Miocene, 710-775 ft. x 20

Figs. 2, 11 **Sigmomorphina subregularis** sp. nov. Holotype. Miocene, 590-620 ft. 2, front view; 11, apertural view. x 17

Figs. 3, 4, 6, 13, 14 (?) **Operculina umbonifera** sp. nov. 13, 14, Side and edge views of holotype. x 19. 3, 4, side and edge views of another specimen. x cir. 20. 6, Section of another specimen. x 25. All from Miocene, 575-620 ft.

Figs. 5, 12 **Discorbis cycloclypeus** sp. nov. Upper Pliocene. 5, Cowandilla Bore. x 19. 12. Abattoirs Bore, 341-500 ft. x 18. Dorsal view in both cases

Fig. 7 **Elphidium adelaidense** sp. nov. Specimen ground down to show shape of chambers and thick dividing walls. Upper Pliocene, 341-500 ft. x 19

Fig. 8 *E.* sp. Miocene, 575-620 ft. x 18

Fig. 9 *Sphaeroidina bulloides* d'Orb. Miocene, 590-620 ft. x 24

Fig. 10 *Operculina victoriensis* Chapman and Parr. Miocene, 590-620 ft. x 13

Fig. 15 *Nonion novozealandicus* Cushman. Lower Miocene, 710-775 ft. x 23

Fig. 16 *Gypsina globulus* (Reuss). Lower Miocene, 710-775 ft. x 24

Plate XIX

Fig. 1 Glauconitic cast of ? *Gypsina* sp. attached to polyzoan. Lower Miocene, 710-820 ft. x 20

Fig. 2 *Planorbulinella inaequilateralis* (Heron-Allen and Earland). Lower Miocene, 710-820 ft. x 28

Figs. 3, 4 *Carpenteria rotaliformis* Chapman and Crespin. Lower Miocene, 710-820 ft. 3, x 18; 4, x 23

Figs. 5, 6 **Elphidium adelaidense** sp. nov. Holotype. Upper Pliocene, 341-500 ft. 5, edge view. x 15; 6, side view, x 17

Fig. 7 *Amphisorus hemprichii* Ehrenberg. Upper Pliocene, 341-500 ft. x 18

Figs. 8, 9, 11, 15 **Rotalia verriculata** sp. nov. 9, Holotype. 11, 15, dorsal views, x 16; 8 ,9, ventral views, x 14. Lower Miocene. 8, 11, 710-775 ft.; 9, 15, 710-820 ft.

Fig. 10 *Miniacina minuta* (Chapman). Lower Miocene, 710-775 ft. x 17

Fig. 12 *Planorbulina mediterranensis* d'Orb. Lower Miocene. 710-820 ft. x 19

Fig. 13 **Discorbis cycloclypeus** sp. nov. Edge view. Upper Pliocene, 341-500 ft. x 19

Fig. 14 (?) *Rotalia* sp. Miocene, 590-620 ft. x 13

Fig. 16 *Elphidium* sp. Miocene. This specimen has been mislaid, and other particulars are not available. It appears to be the same species as that figured on pl. xviii, fig. 8

THE OCCURRENCE OF GALLIUM AND GERMANIUM IN SOME LOCAL COAL ASHES

By W. TERNENT COOKE, D.Sc., A.A.C.I.

Summary

The frequent occurrence of traces of gallium and germanium in coal ash has been pointed out by Ramage (I), Goldschmidt (2), and others (3), and more recently Morgan and Davies (4) have shown that these elements may become concentrated in certain flue dusts to the extent of one per cent. or more, so that their profitable extraction becomes possible. The previously known occurrences of notable concentrations of these elements have been restricted to some very rare sulphide minerals such as argyrodite and germanite, and therefore the recognition of their apparently widespread occurrence in appreciable amounts in flue dusts from coal is a matter of some theoretical and practicable importance. It has seemed of interest therefore to examine some flue dusts from Australian coals for their content of gallium and germanium.

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By W. Ternent Cooke, D.Sc., A.A.C.I.

[Read 8 September 1938]

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The procedure followed was that advocated by Morgan and Davies, in which the dust is distilled with hydrochloric acid of about 6·25 normal (20%). The germanium was recovered from the distillate as sulphide, after separation of arsenic, which is invariably present; the gallium was extracted from the residual liquor by ether, after reduction of the iron to the ferrous state.

In the samples examined considerably less amounts of either element have been found than those reported by Morgan and Davies for many English coal dusts, but the presence of both elements has been noted in most of the samples examined. By working with samples of the order of 100 grammes the analytical results give a reasonable approximation to the actual amounts of gallium and germanium actually present in the dusts.

The majority of the dusts available have been from black coal of permo-carboniferous age, from Newcastle, New South Wales. Those supplied by the courtesy of the South Australian Gas Company have been the richest so far examined. Dust from the waste gas flues in the vertical retort house yielded 0·034% GeO_2, and 0·084% Ga_2O_3, while corresponding dust from the horizontal retorts showed 0·041% GeO_2, and 0·073% Ga_2O_3. Dust from the flues of a Lancashire boiler burning gas coke contained 0·004% GeO_2.

A sample of spent liquor from a still operating on ammoniacal liquor was kindly provided for us in a concentrated form by the Gas Company; this liquor was found to be practically free of germanium.

A sample of dust from the base of the chimney stack of the South Australian Brewing Company, and derived from Newcastle coal, yielded only 0·002% Ga_2O_3, and 0·007% GeO_2.

Dust from a Tasmanian coal of mesozoic age, from Stanhope, supplied by the Tasmanian Cool Storage Company of Launceston, was found to contain 0·005% GeO_2, but showed only a trace of gallium.

Three dusts, supplied by the courtesy of the State Electricity Commission of Victoria, from boiler flues at Yallourn were examined. These dusts from brown coals of tertiary age yielded only traces of both germanium and gallium. This relative deficiency of these elements in dusts from brown as compared with those from black coal agrees with the observations of Fuchs (5), concerning German lignite.

It has been found possible to effect a concentration in some cases by screening the dusts; for example, after screening through a 100-mesh sieve the fine material is sometimes about twice as rich as the original dust.

The possibilities of selectively leaching the dusts with acid or alkaline reagents with a view to concentration have been examined, but the results do not indicate that such methods are applicable to this class of material. Germanium can be leached from the dust by hot concentrated caustic soda, but gallium remains for the most part in the insoluble residue. Subsequent extraction of the germanium from the alkaline lye was difficult on account of the large amount of sodium silicate present. The success achieved by Sebba and Pugh (6) in leaching gallium and germanium from the mineral germanite by sodium hydroxide led to the hope that their process might be applicable to flue dusts, but the fact that germanite is a sulphide combination is evidently a factor in the success of the operation. Apparently the gallium and germanium compounds present in flue dusts are not in a very reactive form, and in view of the high temperatures to which these dusts have been subjected, it seems probable that the elements are present not as simple oxides but possibly as complexes analogous to alumino-silicates.

Acknowledgment is here made of the courtesy of the several Companies who supplied and forwarded the samples examined.

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(6) Sebba and Pugh 1937 The Extraction of Gallium and Germanium from Germanite. Jour. Chem. Soc., 1,371

AN EXAMINATION OF SOME SOILS FROM THE MORE ARID REGIONS OF AUSTRALIA

By J. A. PRESCOT and H. R. SKEWES, Waite Agricultural Research Institute

Summary

During the course of the last few years the opportunity has been taken of securing for the reference collection of soils at the Waite Institute a number of samples from the more inaccessible and arid regions of Australia through the courtesy of the members of expeditions of exploration into these regions. Prominent amongst these collectors have been Mr. Michael Terry, Dr. C. T. Madigan and Mr. N. B. Tindale. The anthropological expeditions from the University of Adelaide have also afforded a number of opportunities for securing such samples. Material has been received in all from some fifty localities, and in some cases from several sites in each locality. These localities may be grouped as representing the following areas: (1) the southern margin of Gibson's Desert between the Warburton Ranges and Laverton, (2) the Warburton Ranges, (3) the Musgrave Ranges and adjacent country, (4) the country between the Granites and Lake Mackay and east thereof, (5) scattered samples north and south of the Macdonnell Ranges, (6) the north-east pastoral country of South Australia, (7) the Lake Eyre basin, and (8) the southern part of Nullarbor Plain. The localities are indicated on the map (fig. 1) and in the accompanying key.

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By J. A. Prescott and H. R. Skewes,
Waite Agricultural Research Institute

[Read 8 September 1938]

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Table I

Key to Locality Plan

Site Number	Soil Samples
1. Paratoo	4588; 4589; 4590, 4591, 4592; 4593
2. Melton	4594, 4595, 4596, 4597; 4598, 4599, 4600; 4601; 4602
3. Koonamore	1851; 216, 217; 218, 219; 220; 221, 222; 223
4. Teetulpa	4606
5. Glenorchy	4603, 4604, 4605
6. Eringa Park	4608; 4609, 4610, 4611; 4612
7. Angorichina	1356
8. Beltana	4585; 4586; 4587
9. Marree	1305, 1306, 1307, 1308, 1309, 1310, 1311
10. Lake Eyre, Muloorina	1316; 1317, 1318, 1319, 1320, 1321, 1322, 1323, 1324
11. Koonibba	1001
12. Nullarbor	477, 478
13. Nullarbor Plain (Gunewarra)	476
14. Gibson's Desert. 247 miles from Warburton Range	2299, 2300, 2301
15. Gibson's Desert. 178 miles from Warburton Range	2303, 2304, 2305
16. Lake Throssell	2311, 2312, 2313

Site Number	Soil Samples
17. Gibson's Desert. 80 miles from Warburton Range ..	2307, 2308, 2309; 2295
18. Jarata (Narratha)	4842, 4843
19. Gibson's Desert. 14 miles from Warburton Range	2297, 2298
20. Warburton Range	2302; 2315, 2316, 2317; 4845; 4846; 2950; 2951; 2953
21. Rawlinson Range	2950
22. Poka. Mann Range	3433, 3434
23. Wala! Soakage. Mann Range	3436, 3437
24. Mount Kintore	3432, 3435
25. Ernabella	3431
26. Ayer's Rock	2713
27. Lambina	5191, 5192, 5193
28. Rumbalara	2712
29. Henbury	5194, 5195
30. Tempe Downs	2714
31. Missionary Plain	5196, 5197, 5198
32. Alice Springs	3419
33. Macdonald Downs	1804, 1805, 1806, 1807
34. Simpson Desert	5199, 5200, 5201
35. Mount Liebig	2711
36. Connor's Well	3421
37. Napperby Creek	3422
38. Cockatoo Creek	2347, 2348, 2349
39. Home Creek	3425, 3430
40. Kunajarai Soak	3428
41. Surprise Rock Hole	3420
42. Lake Mackay	2949
43. Alec Ross Range	3426
44. Brookman Waters	3427
45. False Mt. Russell	3423
46. Wyckham Well	3429
47. The Granites	3424
48. Thompson's Rockhole	4996
49. 12 miles from Archibald's Soak	2973, 2974, 2975
50. 40 miles east of Thompson's Rockhole	4995

The soils are of such diverse origin and so widely scattered geographically that it is not possible to group them very effectively, and no attempt will be made in this account to do more than extract the major generalisations.

For a number of sites carefully sampled profiles are available, and the analytical data for some of these are quoted in full.

Mechanical Analysis

Soils from the Desert Interior

A characteristic feature of the samples from the interior proper is the absence of marked differentiation in the texture of the several horizons. This is especially so in the more sandy soils. It has proved possible, therefore, to treat

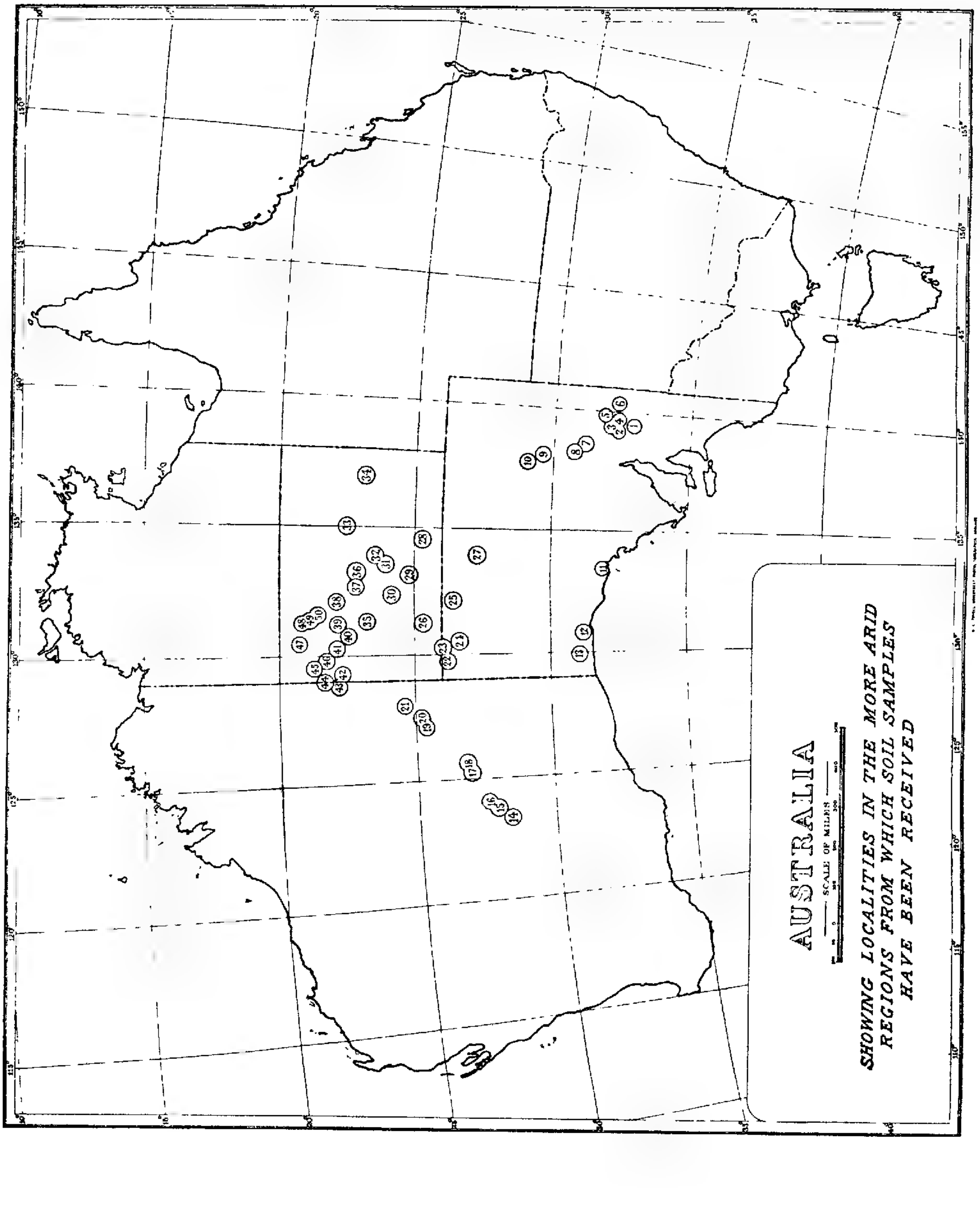
AUSTRALIA
SCALE OF MILES
SHOWING LOCALITIES IN THE MORE ARID REGIONS FROM WHICH SOIL SAMPLES HAVE BEEN RECEIVED

Fig. 1

the samples from each site to a depth of 40 inches as one sample and to average the mechanical analyses to this depth, where such a series was available. Fig. 2 represents, on this basis, the mechanical analyses for all the sites in the central and western desert areas and range country apart from one very heavy profile at Lambina, which is not included.

The range of texture is small and the silt content is very low, the textures falling into the range of sandy loams with the sands of the sandhills at one extremity of the range and a few sandy clay loams at the other. That soils from such a wide geographical area should have such uniform textural characteristics indicates some common process of mechanical sorting of the weathered parent rock.

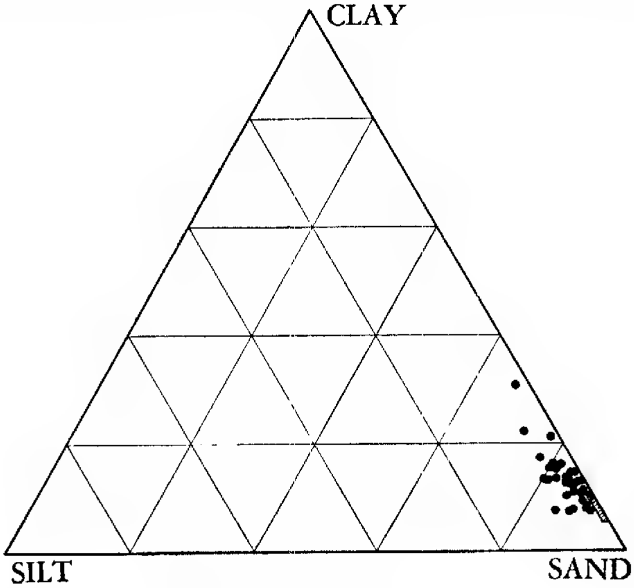

Fig. 2

Triangular diagram (clay + silt + sand = 100) representing the mechanical analyses of soils from the western desert areas and central range country of Australia. Each dot represents the average composition of samples to a depth of 40 inches or less. Samples from the sandhills are indicated by the hatched area.

Soils from the North-East Pastoral Areas of South Australia

In marked contrast with the true desert soils, the group from the north-eastern pastoral area of South Australia may be noted. The mechanical analyses of this group of soils are summarised in fig. 3. The distribution of these analyses within the texture triangle shows approximately equal proportions of clay and silt. Most of these soils are calcareous, and there is also evidence of profile development so far as the occurrence of heavier textures in the subsoils may be regarded as an index of such development.

Desert Sandhills and Drift Sands

A considerable proportion of the arid interior is covered by sandhills, and reference in this connection may be made to the work of Madigan (1936). These sandhills are in most cases fixed by desert grasses belonging mainly to the genus *Triodia;* mulga is also characteristic of the sandhill country.

The sandhills extend into the less arid regions to the north-west, where they are fixed by a low tree savannah woodland known as the "pindan," and to the south by the dwarf sclerophyll woodland known as the "mallee."

In all such areas the removal of the native vegetation by stocking or cultivation results in drift taking place. A series of such loose drifts from the pastoral areas of South Australia has been specially collected, and a comparison is possible with samples from the sandhills of the less accessible parts.

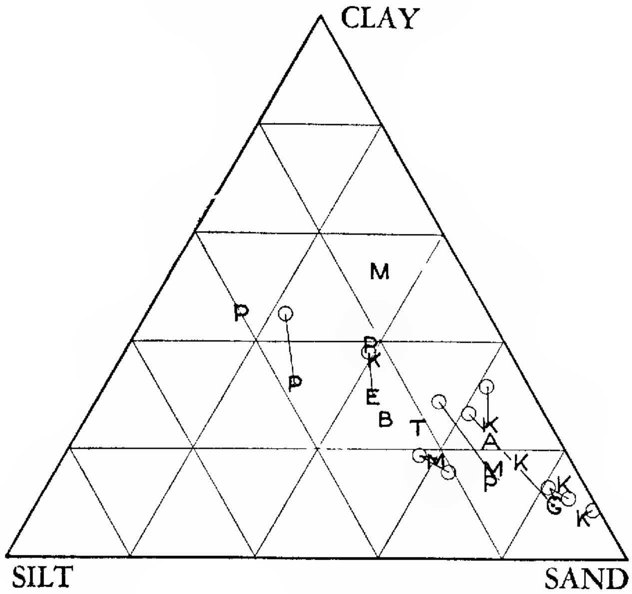

Fig. 3

Triangular diagram representing the mechanical analyses of soils from the North-Eastern and adjacent pastoral districts of South Australia. Circles represent subsoils and are linked to the letters representing the corresponding surface soils. The letters indicate the localities represented: P, Paratoo; M, Melton; B, Beltana; A, Angorichina; K, Koonamore; T, Teetulpa; E, Eringa Park; G, Glenorchy.

A selection of these samples has been examined in some detail, and the sand fractions have been subjected to special analysis by means of sieves. Details regarding these samples are given below; the mechanical analyses and relevant data are given in Table II.

Loose Drifts—

Soil Number:	1316	South shore of Lake Eyre
	4587	Beltana—recent drift in pastoral country
	4601	Melton—drift on fence
	4608	Eringa Park—drift on fence
	4612	Eringa Park—drift round homestead

Fixed Sandhills—

Soil Number: 2712 Rumbalara—flat between hills: 0–12 ins.

2299 Gibson's Desert—red sand carrying mulga and spinifex (*Triodia*) and mallee: 0–9 ins.

2300 Gibson's Desert—red sand: 9–27 ins.

2301 „ „ red sand: 27–43 ins.

2297 „ „ red sand: 0–9 ins.

2298 „ „ red sand: 9–36 ins.

2950 Rawlinson Range, one mile north of west end of range: 0–42 ins.

5199 Simpson (Arunta) Desert. North end. Top half inch of sand—light red sand, carrying stunted desert mallee and spinifex (*Triodia*)

5200 Simpson Desert—red sand: ½–16 ins.

5201 „ „ red sandy loam: 16–30 ins.

218 Koonamore. Botanical Reserve. Sandhill carrying mulga. 0–9 ins.

Table II

Mechanical Analyses and associated Data for Sandy Drifts and fixed Desert Sandhills

Soil number	1316	4587	4601	4608	4612	2712	2299	2300
Depth in inches	0–6	0–2	0–2	0–2	0–2	0–12	0–9	9–27
	%	%	%	%	%	%	%	%
Coarse sand	56·6	28·7	67·1	31·5	36·5	38·8	62·0	59·8
Fine sand	39·2	63·9	23·3	57·5	48·9	55·0	29·5	30·3
Silt	0·1	1·6	2·1	1·7	2·4	0·7	0·6	0·4
Clay	3·5	4·5	5·5	7·0	10·2	5·4	7·7	9·4
Loss on acid treatment	1·0	1·0	2·2	1·9	1·8	0·2	0·2	0·3
Moisture	0·4	0·5	0·5	0·7	1·0	0·2	0·4	0·3
Calcium carbonate	0·07	0·37	1·66	1·25	1·05	tr.	0·00	tr.
Total salts	0·46	0·03	0·03	0·05	0·04	tr.	0·01	0·01
Sodium chloride	0·27	tr.	tr.	0·01	0·01	0·00	tr.	0·00
Reaction (pH)	9·3	9·3	9·2	9·3	9·2	7·0	5·6	5·5

Soil number	2301	2297	2298	2950	5199	5200	5201	218
Depth in inches	27–43	0–9	9–36	0–42	0–½	½–16	16–30	0–9
	%	%	%	%	%	%	%	%
Coarse sand	55·6	52·3	50·6	35·8	42·3	25·0	23·6	52·8
Fine sand	33·3	38·3	39·3	53·4	52·2	64·0	64·2	37·6
Silt	0·5	1·2	0·9	1·2	0·6	0·5	1·0	1·8
Clay	10·5	8·1	8·6	9·6	4·1	9·4	10·2	7·8
Loss on acid treatment	0·2	0·4	0·5	0·1	0·2	0·2	0·2	1·0
Moisture	0·3	0·2	0·3	0·5	0·4	0·9	1·0	0·7
Calcium carbonate	tr.	0·01	0·03	tr.	tr.	0·00	tr.	0·41
Total salts	0·01	0·02	0·07	0·02	tr.	tr.	0·01	0·05
Sodium chloride	tr.	0·01	0·04	tr.	tr.	tr.	tr.	0·02
Reaction (pH)	6·1	6·9	6·9	7·8	7·0	6·6	6·5	8·9

The most characteristic feature of the table is the low content of silt and the invariable presence of clay, varying in amount from 4 to 10 per cent. Even the loose drifts show this clay, some of which is in the form of aggregates, no doubt broken up during the course of mechanical analysis. The sandy soils of the South Australian and Victorian mallee areas show similar characteristics. The amount of salt present and the reaction is a regional characteristic. The drifts from the north-east pastoral areas of South Australia are markedly alkaline and contain calcium carbonate. Those from Gibson's Desert in Western Australia are distinctly acid. Gibson's Desert is characterised by extensive rolling plains of ironstone gravel, and the parent material from which the sandhills are derived is undoubtedly acid in character.

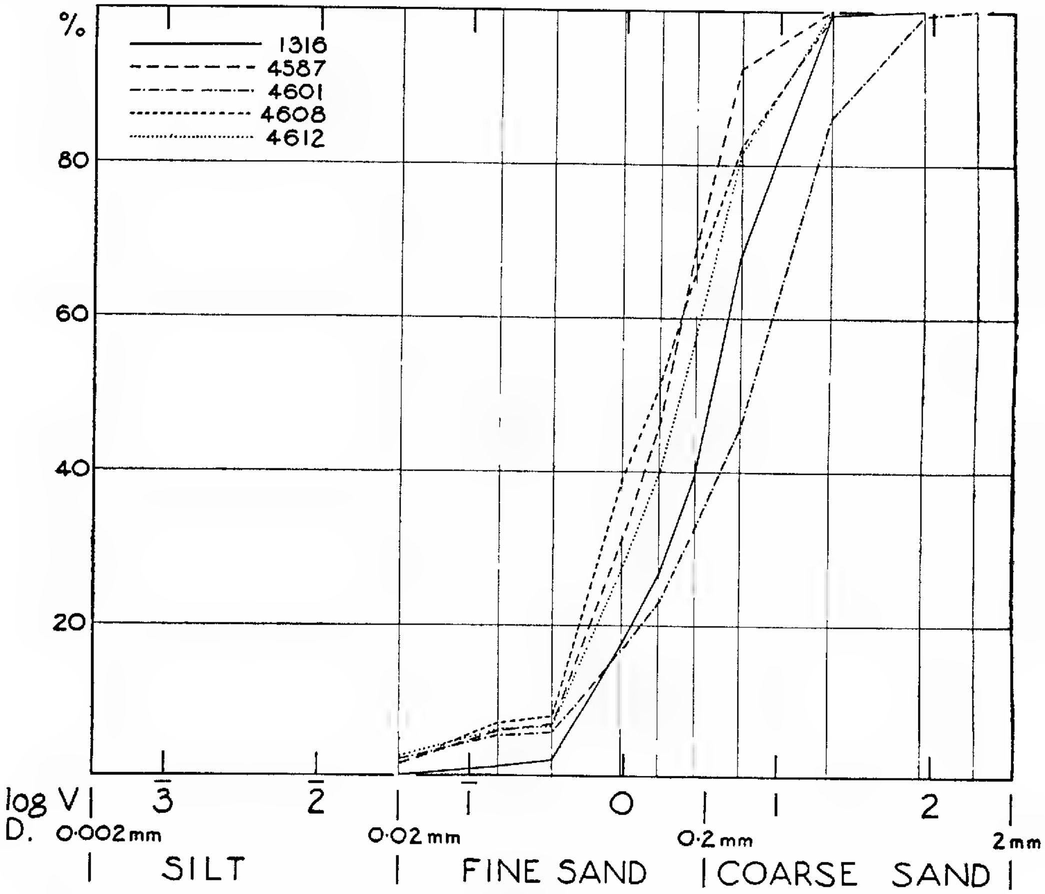

Fig. 4

Summation curves based on separations by means of sieves of the mechanical analyses of drift sands. The virtual absence of silt is to be noted. The samples in addition contain a small proportion of clay not indicated in the above.

These samples were also subjected to mechanical analysis without a preliminary acid treatment. The samples were dispersed by boiling with water to which was added a small amount of sodium carbonate. Silt and clay were removed by gentle rubbing and subsequent decantation. The clean sands were then dried and separated by means of sieves. The summation curves obtained in this way are indicated in figs. 4 and 5. In the case of the five drift samples, the mean curve was determined and analysed to determine the frequency distribution of particles of each of a series of dimensions allowing of eight groups for each of the standard fractions. The frequency curve of fig. 6 emphasises the character of these sands which have a modal frequency near the conventional separation between the coarse and fine sand. The virtual absence of silt in these soils is also easily to be explained in terms of these distributions.

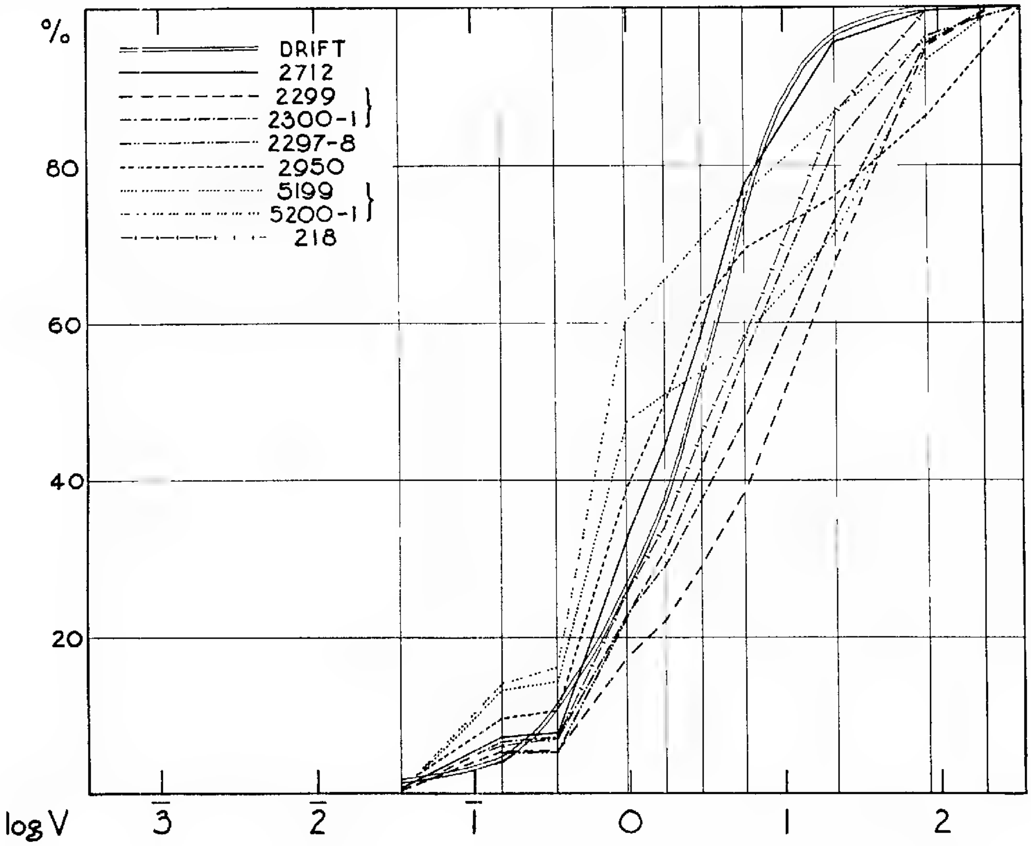

Fig. 5

Summation curves representing the mechanical analyses of the non-colloid fraction of samples from the fixed sandhills. The average composition of the loose drifts represented in figure 4 is superposed.

Two of the samples (Nos. 2950 and 5199) show anomalies which can be interpreted in terms of a mixture of two groups of sand grains. The latter sample is the surface mulch subject to the combined sorting effect of wind and of the rare heavy rains.

Reaction

All the samples have been examined for reaction (pH), using the glass electrode. They form an interesting range, with the calcareous soils of the saltbush steppe of the north-eastern pastoral areas of South Australia as the most alkaline. Samples from the Nullarbor Plain have the same character. The soils from the range country are in general neutral to alkaline, and those from the Granites track and Gibson's Desert are neutral to acid. It is of some possible significance that these two latter groups of soils are representative of the great Australian Peneplain. Presumably the acid conditions are an index of former wetter climatic conditions thus confirming the evidence provided by the abundant ironstone gravel.

The distribution table for the pH values of these soils given in Table III summarises the information available.

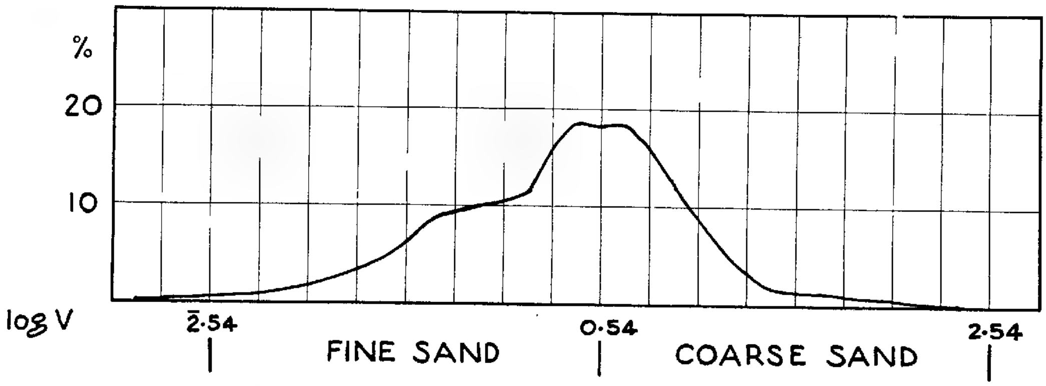

Fig. 6

Distribution curve of the average mechanical composition of the non-colloid fraction of drift sands, allowing of eight subdivisions for each of the standard fractions: fine sand and coarse sand. The absence of silt and the fact that the modal frequency is about the conventional division between coarse sand and fine sand at a diameter of 0·2 mm. are again emphasised.

TABLE III

Illustrating the Range of Values for the Reaction of Soils and Subsoils in Five Groups of Soils

pH	5.1 -5.5	5.6 -6.0	6.1 -6.5	6.6 -7.0	7.1 -7.5	7.6 -8.0	8.1 -8.5	8.5 -9.0	9.1 -9.5	9.6 -10.0	10.1 -10.5
North-East Pastoral Areas, South Australia:											
Surface soils						2	4	7	2	1	1
Subsoils							2	3	3	1	
Central Western Range Country:											
Surface soils				1	2	3	1	1	1		1
Subsoils					2	1			2		
Macdonnell Range Country:											
Surface soils		1		4	7		1	2			
Subsoils			1		3	2	2	1			
Granites Track and Lake Mackay:											
Surface soils	1	2	4	3	1						
Subsoils		1	1	1							
Gibson's Desert:											
Surface soils	3	3		1	1						
Subsoils	2	1	2	2							

Soluble Salts

The vast majority of the samples examined are relatively free of salt with the exception of the South Australian samples from the pastoral areas and from the regions of Lake Eyre and the Nullarbor Plains. None of the remaining surface soils contains as much as 0·05 per cent. of total soluble salts, and few of the subsoils contain as much as 0·10 per cent.

The saltbush country shows, however, much higher amounts, and reference may be made to the data given later relating to individual soil profiles. Some exceptionally saline soils may be noted, however—these have usually been associated with bare patches and wind-swept areas. It is apparent that many such bare areas are not due so much to erosion and loss of vegetation by stocking as to inherent infertility through the natural presence of soluble salts.

Some examples of these more saline areas are tabulated below.

Soil No.	Locality	Depth in Inches	Salt Content (%)	Vegetation
4606	Teetulpa	0–6	0·12	wind swept; sandalwood
4602	Melton	0–8	0·14	wind swept; mulga floodplain
4585	Beltana	surface	0·20	wind swept area
1316	Lake Eyre	surface	0·46	bare sandhills near Lake
4588	Paratoo	0–12	0·68	no growth
1851	Koonamore	0–7	0·91	saltbush
216/7	Koonamore	0–12	1·38	sandalwood
4593	Paratoo	0–12	2·29	no growth
1305/6	Marree	0–9	2·60	bare ground

Reference may also be made here to the nature of samples from the immediate vicinity of salt lakes and from the bed of the lakes themselves. Madigan (1930) has already reported upon the muds from Lake Eyre. Samples have been examined during the course of the present work from Lake Throssell, 200 miles south-west of the Warburton Range, and from Lake Mackay. These results are quoted in the following table.

Table IV

Mechanical Analyses and relevant Salt Data for Soils from Lake Mackay and Lake Throssell

Locality	Lake Throssell			Lake Mackay
Sample number	2311	2312	2313	2949
Depth in inches	0–18	18–27	27–43	0 36
Coarse sand	4·2	4·0	34·0	19·5
Fine sand	4·3	5·0	18·0	34·7
Silt	1·8	1·6	1·9	2·2
Clay	10·5	8·1	13·6	9·9
Loss on acid treatment	64·5	65·3	25·2	28·5
Moisture	16·6	16·8	7·7	5·5
Calcium carbonate	0·04	0·01	0·77	0·004
Gypsum	66·9	67·0	23·8	25·4
Sodium chloride	0·53	0·72	0·95	4·90

Chemical Analyses

As a measure of the fertility level of these soils analyses have been made on representative samples using the standard hydrochloric extracts for phosphate and potash, the method of dry combustion for carbon, and the Kjeldahl estimation for total nitrogen. These data are given in Table V, together with correlated information such as the clay content and total salts.

Two ratios have been calculated—those of carbon to nitrogen and of potash to the clay as estimated by the international method of mechanical analysis. The ratios of carbon to nitrogen tend towards the low side, with three very low values for samples No. 5200, 5192 and 1306. The phosphate levels are variable and show some relation to the native vegetation. The outstanding feature in this respect is the high level of phosphate in the soils of the north-eastern pastoral region of South Australia—a level which is higher than that generally encountered in the wheat belt further south.

The ratio of potash to clay shows again two outstanding generalisations—the acid soils of the Granites country and of Gibson's Desert showing low ratios in this respect, further evidence of leaching during a former geological cycle, while the alkaline soils of the pastoral region mentioned above show uniformly high values.

This region has a high reputation amongst stock owners for the production of healthy sheep, and from the point of view of soil fertility must be regarded as one of the outstanding areas in South Australia.

Sample No. 3431 shows a very high level of fertility—this sample is taken near the native waterhole at Ernabella in the Musgrave Ranges and is associated with an aboriginal camping ground.

The native vegetation of these semi-arid and arid soils covers a range which includes two main associations of *Triodia*, those of the desert sandhills and those of the sand plains of Gibson's Desert and of the Tanami country; the associations including mulga and grasses, the low tree savannahs of the plains between the ranges and the shrub steppes of saltbush or bluebush.

From the native vegetation recorded with many of the samples received, a tentative scale of fertility may be attempted. *Triodia* (spinifex or porcupine grass) is an index of low fertility, while saltbush appears to be associated only with the highest level of plant nutrients.

In general the level of phosphate is the main index of fertility, and on this basis the following generalisations may be derived.

Vegetation	Range of Phosphate Content (P_2O_5)
Porcupine grass	0·006 – 0·023%
Mulga with grass	0·023 – 0·053%
Low tree savannah	0·041 – 0·060%
Bluebush	0·032 – ·058%
Saltbush	0·065 – 0·098%

The table suggests three levels of fertility, the first up to 0·023%, the second from 0·023% to 0·060%, and the third above 0·060% P_2O_5.

TABLE V

Chemical Analyses of Soils

Sample No.	Depth in Inches	Site No.	Clay	Total Soluble Salts %	Potash K_2O %	Phosphate P_2O_5 %	Nitrogen N %	Organic Carbon C %	Ratios C/N	Ratios K_2O per 100 gm. Clay
Lake Mackay–Granites:										
3424	0–42	47	14·6	0·01	0·18	0·021	0·015	0·13	8·9	1·23
3426	0–34	43	30·3	0·02	0·54	0·031	0·024	0·20	8·2	1·79
3429	0–26	46	14·6	0·01	0·16	0·015	0·015	0·15	10·2	1·10
4995	surface	50	7·2	0·01	0·09	0·016	0·011	—	—	1·25
4996	surface	48	12·9	0·02	0·26	0·069	0·035	—	—	2·01
2973	0–6	49	11·7	0·01	0·11	0·015	0·015	0·21	13·7	0·94
Macdonnell Range Country:										
5200	1–16	34	9·4	0·01	0·18	0·016	0·024	0·08	3·4	1·92
1804	surface	33	7·8	0·02	0·32	0·033	0·021	—	—	4·10
5192	2–14	27	43·2	0·05	0·65	0·053	0·029	0·14	4·9	1·51
5194	0–26	29	10·5	0·01	0·23	0·023	0·014	0·11	7·7	2·19
5197	2–10	31	11·5	0·01	0·32	0·027	0·024	0·24	9·8	2·79
3421	0–42	36	11·4	0·01	0·16	0·015	0·004	0·12	8·9	1·40
2712	0–12	28	5·4	0·01	0·14	0·021	0·010	0·08	8·0	2·59
2711	surface	35	13·5	0·02	0·41	0·042	0·038	—	—	3·04
Central and Western Ranges:										
2713	surface	26	10·9	0·02	0·24	0·023	0·027	—	—	2·20
3431	0–12	25	6·8	0·22	0·47	0·196	0·048	0·53	11·1	6·91
3436	0–6	23	8·6	0·01	0·23	0·041	0·029	0·21	7·1	2·68
2315	0–9	20	9·6	0·05	0·22	0·015	0·026	0·21	8·2	2·29
3432	0–6	24	7·7	0·02	0·09	0·006	0·020	0·22	10·8	1·17
3433	0–6	22	13·8	0·02	0·26	0·060	0·022	0·21	9·4	1·87
Gibson's Desert:										
4843	1–18	18	15·8	0·05	0·12	0·037	0·023	—	—	0·76
2299	0–9	14	7·7	0·01	0·09	0·012	0·007	0·10	14·4	1·17
2297	0–9	19	8·1	0·02	0·11	0·019	0·011	0·11	10·5	1·36
2295	0–6	17	9·2	0·01	0·09	0·027	0·022	0·26	11·6	0·98
2307	0–9	17	17·0	0·01	0·15	0·045	0·023	—	—	0·88
2303	0–9	15	11·5	0·01	0·09	0·024	0·022	0·29	13·1	0·78
South Australia—N.E. Pastoral District:										
4591	0–12	1	37·8	0·11	1·55	0·085	0·136	1·20	8·8	4·11
4589	0–9	1	16·5	0·06	0·80	0·049	0·044	0·33	7·6	4·85
4595	0–11	2	24·4	0·08	1·34	0·098	0·080	0·65	8·1	5·50
4599	0–9	2	20·9	0·08	0·87	0·058	0·045	0·30	6·7	4·17
4610	0–12	6	30·0	0·07	0·92	0·067	0·057	0·47	8·3	3·06
4604	0–12	5	15·2	0·05	0·52	0·032	0·030	0·24	7·9	3·43
1851	0–7	3	16·1	0·91	0·87	0·065	0·065	0·52	7·9	5·40
221	0–10	3	11·0	0·05	0·56	0·038	0·031	—	—	5·09
Miscellaneous (South Australia):										
1356	surface	7	18·5	0·09	—	0·076	—	—	—	—
476	surface	13	28·0	0·09	1·22	0·069	0·164	—	—	4·36
1306	3–9	9	41·3	3·08	0·99	0·071	0·021	0·09	4·4	2·39
1317	0–9	10	8·3	0·14	0·16	0·031	0·007	0·062	8·8	1·93

Some Characteristic Profiles

Profile development in desert and semi-desert areas is little understood, and much field work will be required before a full interpretation is possible. Field estimates of structure and texture are not usually available owing to the conditions under which the samples have been collected, but a selection of samples representing twelve profiles has been taken and the analytical data relating thereto are given below.

The leaching factors responsible for the development of horizons in soil profiles are not common in the desert environment, so that marked structural differences in the successive depths of soil are not to be expected. Attention may be called, however, to the lamination that occurs in soils from the semi-desert regions of Western Australia (Teakle, 1936). The type of structure described by Teakle can only occur in the closed basins of the areas of internal drainage, characteristic of arid regions, and represents a process of accumulation and cementation rather than of leaching and deflation. Gautier (1928) has called attention to the importance of water as the main geological factor responsible for erosion in desert regions—wind plays a subsequent part mainly in the modelling of the surface features. No cases of lamination have been met in the samples under present consideration.

One feature, however, of the desert grassland and of the shrub steppe is the accumulation of a loose drift with plant debris round the base of the grass clump or of the bush. This drift may be considered as a super-surface or Ao horizon and is usually of loose texture and forms an admirable seed bed for the ephemeral and seedling perennial vegetation. The destruction of the perennial grasses or bushes which constitute the nurse plants, with the consequent loss of this characteristic horizon, may be considered to be a major source of difficulty in the regeneration of the vegetation of these areas.

The selected profiles will be dealt with individually, and the complete data relating to them recorded as a source of reference material for other workers in this field. The site numbers quoted are those given on the map of fig. 1..

Site No. 31—Missionary Plain, Central Australia, 12 miles south-west of Alice Springs. Native vegetation—a low tree savannah woodland dominated by ironwood *(Acacia estrophiolata)* and mulga *(Acacia aneura)*, with *Aristida* and *Eragrostis* species as the principal grasses. Collected by R. L. Crocker.

Samples: 5196: 0-2 ins. Brown sand
5197: 2–10 ins. Brown sand
5198: 10–46 ins. Red-brown sand loam; no gravel in the profile.

The analyses below do not reveal any marked separation of horizons in the soil. The reaction is neutral and the fertility level moderate in terms of phosphate and potash.

Sample number	5196	5197	5198
Depth in inches	0–2	2–10	10–46
Mechanical Analysis:	%	%	%
Coarse sand	32·7	29·6	27·0
Fine sand	55·3	53·9	53·0
Silt	2·5	3·6	2·0
Clay	7·6	11·5	15·7
Loss on acid treatment	0·4	0·3	0·3
Moisture	0·8	1·0	1·7
Chemical Analysis:			
Calcium carbonate	0·01	0·00	0·00
Total soluble salts	0·01	0·01	0·01
Sodium chloride	tr.	tr.	tr.
Organic carbon	0·49	0·24	—
Nitrogen	0·05	0·02	—
Phosphate (P_2O_5)	0·05	0·03	—
Potash (K_2O)	0·26	0·32	—
Reaction (pH)	7·1	7·0	7·2

Site No. 27—Lambina Station, South Australia, 100 miles north-west of Oodnadatta. Samples collected by R. L. Crocker. Native vegetation: An association dominated by mulga *(Acacia aneura)* with Eremophilas and Cassias. Stony gibber plain.

Samples: 5191: 0 2 ins. Brown sandy loam containing 31 per cent. of gravel.

5192: 2–14 ins. Brown sandy clay loam to clay loam with 4 per cent. of gravel.

5193: 14–18 ins. Red-brown medium clay, without gravel.

This profile represents a heavy type of soil frequently associated with gibber country.

The surface two inches differs markedly in texture from the soil at greater depth. Surface wash and the removal of the finer particles by wind, rather than leaching, no doubt contribute to this change. The absence of gravel or stone in the lower horizon is noteworthy.

The reaction is neutral in the surface to markedly alkaline at the lower depths. The fertility level is moderately high.

Sample number	5191	5192	5193
Depth in inches	0–2	2–14	14–18
Mechanical Analysis:			
	%	%	%
Coarse sand	40·8	23·1	20·0
Fine sand	42·5	23·7	21·0
Silt	7·0	3·3	2·2
Clay	8·4	43·2	49·2
Loss on acid treatment	0·3	0·7	1·4
Moisture	1·2	6·4	7·3
Chemical Analysis:			
Calcium carbonate	tr.	tr.	0·11
Total soluble salts	0·01	0·05	0·09
Sodium chloride	0·00	0·02	0·04
Organic carbon	0·15	0·14	—
Nitrogen	0·02	0·03	—
Phosphate (P_2O_5)	0·06	0·05	—
Potash (K_2O)	0·24	0·65	—
Reaction (pH)	7·1	8·1	8·9

Site No. 49—Archibald's Soak, Central Australia. From an area typical of the flat desert country, about 12 miles from Archibald's Soak and 290 miles from Alice Springs on the Granites track. Collected by C. T. Madigan. This area is a high level peneplain characterised by a vegetation association which includes *Triodia* as the dominant grass, with Acacias, Mallee, Eucalypts and Hakeas.

The analyses reveal little evidence of profile development except possibly a moderate leaching of the surface soil. The whole profile is, however, acid in reaction, suggesting survival from a period when rainfall was heavier than at the present time. The fertility level is low.

Sample number	2973	2974	2975
Depth in inches	0–6	6–12	12–18
Mechanical Analysis:			
	%	%	%
Coarse sand	51·7	51·3	48·4
Fine sand	35·8	34·7	36·3
Silt	1·2	1·0	1·9
Clay	11·7	13·5	13·8
Loss on acid treatment	0·0	0·1	0·1
Moisture	0·4	0·5	0·5

Chemical Analysis:

Calcium carbonate	0·00	tr.	tr.
Total soluble salts	0·01	0·09	0·01
Sodium chloride	0·00	0·00	0·00
Organic carbon	0·21	—	—
Nitrogen	0·01	—	—
Phosphate (P_2O_5)	0·02	—	—
Potash (K_2O)	0·11	—	—
Reaction (pH)	5·5	6·0	6·3

Site No. 20—Warburton Range, Western Australia. Collected by Michael Terry. Camp 25 on expedition of 1931, 300 yards from Warburton Creek.

The sample is collected from a travertine rise on the west bank of the creek. The flood waters, in overflowing on the hot dry banks, deposit calcium carbonate, giving rise to travertine or "opaline" rises which are specially characteristic of the rivers of the Murchison and Gascoyne districts and of the north-west of Western Australia.

The differences in the three horizons sampled are associated principally with the differences in the content of calcium carbonate. The fertility level in terms of plant food is low.

All the samples are very gravelly, the proportion of gravel in the three original samples being successively 27, 55 and 51 per cent. This gravel was calcareous in character.

Sample number	2315	2316	2317
Depth in inches	0–9	9–18	18–27
Mechanical Analysis:	%	%	%
Coarse sand	10·2	7·4	7·9
Fine sand	75·2	69·6	58·5
Silt	2·0	2·3	2·1
Clay	9·6	11·4	12·2
Loss on acid treatment	2·5	9·7	19·0
Moisture	0·6	0·7	1·3
Chemical Analysis:			
Calcium carbonate	1·73	8·66	17·71
Total soluble salts	0·05	0·04	0·04
Sodium chloride	tr.	tr.	tr.
Organic carbon	0·21	—	—
Nitrogen	0·03	—	—
Phosphate (P_2O_5)	0·02	—	—
Potash (K_2O)	0·22	—	—
Reaction (pH)	8·9	9·2	9·2

Site No. 17—Gibson's Desert, Western Australia, 80 miles from Hazlett's Well, in the Warburton Range. Collected by Michael Terry.

The samples are taken from an ironstone gravel flat—the gravel representing, successively, 32, 41 and 37 per cent. of the original samples. The soils, to a depth of 18 inches, are acid.

The fertility level with respect to phosphate is moderate, with respect to potash it is low. The gravel has been found (Prescott, 1934) to contain 49·0 per cent. of iron oxide (Fe_2O_3).

Sample number		2307	2308	2309
Depth in inches		0–9	9–18	18–27
Mechanical Analysis:				
		%	%	%
Coarse sand		21·6	17·8	19·8
Fine sand		57·0	53·8	46·4
Silt		3·8	4·6	6·8
Clay		17·0	23·1	26·0
Loss on acid treatment		0·3	0·0	0·3
Moisture		0·7	1·2	2·0
Chemical Analysis:				
Calcium carbonate		0·004	0·007	0·029
Total soluble salts		0·011	0·014	0·073
Sodium chloride		0·002	0·003	0·012
Organic carbon		—	—	—
Nitrogen		0·023	—	—
Phosphate	(P_2O_5)	0·045	—	—
Potash	(K_2O)	0·15	—	—
Reaction	(pH)	5·2	5·3	6·6

Site No. 15—Gibson's Desert, Western Australia, 178 miles from Hazlett's Well. Collected by Michael Terry. The lower slope of an undulation in ironstone gravel country. As in the previous group of samples the proportion of gravel is high and the soils are acid. Fertility level is low.

The gravel content of the three horizons is 40, 70 and 71 per cent. of the original samples. The composition of the gravel from this profile has been discussed previously (Prescott, 1934)—it was found to contain 30·8 per cent. of iron oxide (Fe_2O_3).

Sample number	2303	2304	2305
Depth in inches	0–9.	9–18	18–26
Mechanical Analysis:	%	%	%
Coarse sand	35·1	37·4	35·6
Fine sand	50·5	45·4	45·6
Silt	2·5	3·3	4·3
Clay	11·5	12·9	13·3
Loss on acid treatment	0·2	0·2	0·4
Moisture	0·3	0·5	0·6

Chemical Analysis:				
Calcium carbonate		0·012	0·006	—
Total soluble salts		0·014	0·027	0·015
Sodium chloride		0·002	0·002	0·002
Organic carbon		0·289	0·290	0·222
Nitrogen		0·022	0·026	0·025
Phosphate	(P_2O_5)	0·024	0·024	0·022
Potash	(K_2O)	0·09	0·11	0·13
Reaction	(pH)	5·9	6·0	6·2

Site No. 10—Muloorina Peninsula, South Australia; south of Lake Eyre, 5 miles from the Lake. Collected by J. A. Prescott.

This series of soil horizons is representative of the consolidated sandhills characteristic of the immediate vicinity of Lake Eyre. The surface of the country is relatively loose and, when eroded away, reveals a firm subsoil with a wide polygonal pattern of gentle domes. No cracks were to be observed between them at the time of sampling (Madigan Expedition, Camp 1, Bore 9, December, 1929). The only vegetation was dead cotton bush *(Kochia aphylla)* and saltbush, with occasional needlebush *(Hakea)*.

In the vicinity of the Lake gypsum is very common. The mud of the Lake itself consists of a saturated solution of brine with crystals of gypsum and common salt, some calcium carbonate and much sand. Reference may be made to Madigan (1930) for further details. The mean annual rainfall at Muloorina is 4 inches, so that leaching is restricted to the most soluble constituents. Calcium carbonate is present throughout the profile but has been leached down to a certain extent, reaching its maximum in the fourth nine inches. Sodium chloride is at its maximum in the third nine inches, while gypsum becomes prominent at 54 inches. For such light soils the phosphate content (0·03%) is fairly high. The samples are all markedly alkaline.

Sample number	1317	1318	1319	1320	1321	1322	1323	1324
Depth in inches	0–9	9–18	18–27	27–36	36–45	45–54	54–63	63–72
Mechanical Analysis:	%	%	%	%	%	%	%	%
Coarse sand	45·5	36·0	35·6	35·0	33·6	33·8	39·4	36·4
Fine sand	41·2	44·8	43·2	42·4	45·5	45·0	35·1	37·9
Silt	0·3	0·6	1·3	1·2	1·0	0·9	0·9	0·6
Clay	8·3	9·2	8·4	9·1	8·6	8·7	8·4	8·3
Loss on acid treatment	4·4	7·1	10·0	10·7	10·4	11·2	14·4	14·1
Moisture	1·1	1·5	1·7	1·4	1·1	1·3	2·2	2·4
Chemical Analysis:								
Calcium carbonate	3·40	6·16	8·09	8·71	8·02	7·69	7·70	5·83
Gypsum	0·08	0·20	0·23	0·27	0·25	2·13	8·80	7·90
Sodium chloride	0·22	0·23	0·37	0·29	0·22	0·19	0·18	0·20
Reaction (pH)	9·7	9·6	9·5	8·7	9·6	8·3	8·2	8·2

Site No. 5—Glenorchy, South Australia. Springs paddock. Collected by J. A. Prescott. Country carrying saltbush and bluebush, with mulga in immediate neighbourhood.

The first sample represents the super-surface horizon (Ao) round the bushes which act as nurse plants—this drift provides a favourable seed bed, and it is the loss of this horizon by wind erosion which gives rise to the major soil problem in relation to pasture regeneration in these areas.

The horizon is measured from the general surface of the soil upwards, and not downwards. Soils at Glenorchy are affected by the neighbourhood of granite outcrops. They are light in texture and not particularly rich in plant foods. The samples contained 1 to 2 per cent. of quartz gravel.

Sample number	4603	4604	4605
Depth in inches	2–0	0–12	14–26
Mechanical Analysis:	%	%	%
Coarse sand	51·3	52·0	33·5
Fine sand	38·0	27·1	22·8
Silt	2·2	2·8	2·2
Clay	7·1	15·2	24·3
Loss on acid treatment	0·8	2·2	15·7
Moisture	0·7	1·8	3·3
Chemical Analysis:			
Calcium carbonate	0·11	1·30	14·16
Total soluble salts	0·027	0·053	0·33
Sodium chloride	0·002	0·011	0·21
Organic carbon	0·188	0·237	0·206
Nitrogen	0·024	0·030	—
Phosphate ... . (P_2O_5)	0·029	0·032	—
Potash .... (K_2O)	0·37	0·52	—
Reaction .... (pH)	9·2	9·5	9·3

Site No. 2A—Melton, South Australia. Collected by J. A. Prescott.

From Round Hill, near the boundary of Koonamore. Country carries saltbush and bluebush. The samples resemble in many respects those from Glenorchy quoted above. They are better supplied with plant foods, however.

Sample number	4598	4599	4600
Depth in inches	2–0	0–9	9–20
Mechanical Analysis:	%	%	%
Coarse sand	47·8	37·9	26·4
Fine sand	30·2	28·2	23·5
Silt	6·2	8·4	5·9
Clay	13·0	20·9	28·9
Loss on acid treatment	1·5	3·2	13·2
Moisture	1·3	2·3	3·7

Chemical Analysis:				
Calcium carbonate		0·45	2·08	11·65
Total soluble salts		0·032	0·076	0·36
Sodium chloride		0·005	0·029	0·23
Organic carbon		0·322	0·299	—
Nitrogen		0·043	0·045	—
Phosphate	(P_2O_5)	0·057	0·058	—
Potash	(K_2O)	0·69	0·87	—
Reaction	(pH)	9·1	9·0	8·9

Site No. 26—Melton, South Australia. Collected by J. A. Prescott.

From the Woolshed paddock. The vegetation is young saltbush. The characteristics are similar to the soils from the preceding sites, but the level of phosphate is high. The soil is more calcareous and the profile bottoms on parent slaty and calcareous rock. In this and following cases the mechanical analyses are reported by a method in which the dispersion is carried out by means of sodium hypobromite without a preliminary treatment with acid, so as to give a more correct representation of the texture in view of the presence of much calcium carbonate. Sample No. 4596 contained 15 per cent., and No. 4597, 16 per cent. of calcareous gravel.

Sample number		4594	4595	4596	4597
Depth in inches		2–0	0–11	12–20	20–27
Mechanical Analysis (Hypobromite Method):		%	%	%	%
Coarse sand		22·5	26·3	17·9	10·0
Fine sand		50·8	33·9	39·0	53·2
Silt		16·9	21·8	24·2	21·0
Clay		9·8	18·0	18·9	15·8
Chemical Analysis:					
Calcium carbonate		1·60	2·17	17·16	18·00
Total soluble salts		0·056	0·080	0·53	0·56
Sodium chloride		0·007	0·033	0·38	0·39
Organic carbon		1·128	0·650	0·489	—
Nitrogen		0·112	0·080	—	—
Phosphate	(P_2O_5)	0·094	0·098	—	—
Potash	(K_2O)	1·12	1·34		—
Reaction	(pH)	8·9	8·9	8·2	8·6

Site No. 1—Paratoo, South Australia. Collected by J. A. Prescott.

The profile was sampled in the mustering paddock on a saltbush flat. The samples show the same characteristics as the previous ones from the North-East pastoral country. They are calcareous and well supplied with plant foods.

Sample No. 4592 contained 2 per cent. of slaty gavel. Exchangeable bases were determined in this particular profile. The results are given below.

Sample number	4590	4591	4592
Depth in inches	2–0	0–12	12–24
Total Exchangeable Bases (m.e. per 100 gm.)	25·51	25·74	19·35
Proportion as Calcium	64·5	68·8	65·6
Magnesium	15·1	17·9	25·0
Potassium	15·7	8·2	2·3
Sodium	4·7	5·1	7·1

The soil shows no evidence of solonisation. The relatively high potassium in the super surface horizon is probably due to plant remains.

Sample number	4590	4591	4592
Depth in inches	2–0	0–12	12–24
Mechanical Analysis (Hypobromite Method):			
	%	%	%
Coarse sand	1·6	2·4	1·7
Fine sand	22·0	27·7	19·9
Silt	54·9	37·6	33·3
Clay	21·5	32·3	45·1
Chemical Analysis:			
Calcium carbonate	3·50	3·43	36·14
Total soluble salts	0·233	0·112	0·069
Sodium chloride	0·067	0·033	0·020
Organic carbon	2·353	1·200	0·492
Nitrogen	0·242	0·136	—
Phosphate (P_2O_5)	0·120	0·085	—
Potash (K_2O)	1·65	1·55	—
Reaction (pH)	8·3	8·8	9·2

Site No. 6—Eringa Park, South Australia. Collected by J. A. Prescott. The samples come from the Warwirra Paddock and from a typical saltbush plain. The soils are similar in character to the preceding ones and are calcareous. Sample No. 4610 contained 2 per cent., and No. 4611, 12 per cent. of calcareous gravel.

Sample number	4609	4610	4611
Depth in inches	1–0	0–12	12–25
Mechanical Analysis (Hypobromite Method):			
	%	%	%
Coarse sand	0·7	8·0	7·2
Fine sand	67·2	37·0	31·6
Silt	18·1	25·5	23·1
Clay	14·0	29·5	38·1

Chemical Analysis:

Calcium carbonate		2·80	13·33	24·95
Total soluble salts		0·063	0·071	0·123
Sodium chloride		0·012	0·013	0·021
Organic carbon		1·129	0·473	0·323
Nitrogen		0·114	0·057	—
Phosphate	(P_2O_5)	0·087	0·067	—
Potash	(K_2O)	1·08	0·92	—
Reaction	(pH)	9·1	9·7	10·0

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ON THE GROWTH OF THE SHEEP POPULATION IN TASMANIA

By J. DAVIDSON, D.Sc, Waite Agricultural Research Institute, University of Adelaide

Summary

Tasmania has an area of 16,778,000 acres, of which 47 percent consists of unoccupied country. A relatively small area is cultivated; the area under crop in 1936-7 was 263,251 acres, together with 45,060 acres of fallow land. The land utilization regions of the country have been analysed in a recent publication (Lowndes and Maze, 1937).

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By J. Davidson, D.Sc.
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[Read 13 October 1938]

I Introduction

Tasmania has an area of 16,778,000 acres, of which 47 per cent. consists of unoccupied country. A relatively small area is cultivated; the area under crop in 1936-7 was 263,251 acres, together with 45,060 acres of fallow land. The land utilization regions of the country have been analysed in a recent publication (Lowndes and Maze, 1937).

The first European settlement in Tasmania was established by Lt. Bowen at Risdon Cove, in September, 1803. Colonel David Collins moved the settlement to the present site of Hobart, in February, 1804. In 1804, also, Colonel Paterson formed a settlement near the mouth of the Tamar; it was removed to the present site of Launceston two years later. The northern and southern portions of Tasmania were administered from Launceston and Hobart, respectively, until 1812, when the colony was united under one administration with headquarters in Hobart. During the first 20 years of its development Tasmania was an appendage of New South Wales; it was proclaimed a separate colony in 1825.

The native inhabitants of the island had not practised any form of agriculture, so that the European settlers entered upon a country whose native vegetation had been undisturbed except for occasional bush fires. A system of grants of free lands to settlers was introduced within the first ten years of settlement; the system remained in force until 1864, at which time the area of approved grants amounted to 1¼ million acres. The early selections of land were naturally made about Hobart and Launceston. Development extended from these centres along the Derwent and the Tamar. The direction and rate of progress of the advance of settlement was determined largely by the physical features of the country and the native vegetation.

II Fitting the Sheep Data to the Verhulst-Pearl Logistic Curve

The annual records of sheep numbers in Tasmania from 1816 onwards were obtained through the courtesy of the Deputy Commonwealth Statistician, Hobart. Complete returns are not available for 1816, 1817, 1820 and 1822-26. The annual records are plotted in fig. 1. The mean annual number of sheep for five-year periods is given in Table I; in each case the number is allotted to the mid-year of the appropriate five-year period.

TABLE I

Showing the Mean Annual Sheep Population in Tasmania for the Five-year Periods 1819-1924 (Mid-years), and Values calculated from the Growth Curve.

Mid-year x	Population in Thousands y		Mid-year x	Population in Thousands y	
	Observ.	Calc.		Observ.	Calc.
1819 (1)	161	187	1874	1625	1660
1824	—	327	1879	1837	1665
1829	574	534	1884	1731	1667
1834	795	793	1889	1562	1669
1839	1050	1068	1894	1612	1670
1844	1278	1288	1899	1646	1670
1849	1867	1447	1904	1629	1670
1854	1901	1546	1909	1764	1670
1859	1702	1603	1914	1720	1670
1864	1726	1635	1919	1691	1670
1869	1500	1652	1924	1631	1670

(1) Only three years are available for this period.

The sheep numbers for the five-year periods given in Table I have been fitted to the Verhulst-Pearl logistic curve, having the formula:

$$y = \frac{1670}{1 + e^{240.81245 - 0.13125x}}$$

The upper asymptote, 1670, was obtained by taking the average population for the five-year periods 1859-1924. The calculated curve is shown in fig. 1; the observed and calculated figures are given in Table I.

The curve shows that, under the conditions of development of the sheep industry up to 1846, the expected saturation density on the natural pastures of the State would be 1,670,000 sheep. This density was attained towards the end of the 1840's. From the beginning of the 1850's onwards the population oscillated about this value for about 70 years. Compared with South Australia (Davidson, 1938) the rate of growth is slower. This is related to differences in the physical features, climate and early political history of the two States. The marked temporary fluctuations in sheep numbers found in South Australia, due to drought periods, are less pronounced in the case of Tasmania.

III PROGRESS OF THE SHEEP POPULATION

(a) First Period, 1804-1846

In the first decade of settlement, development was necessarily slow. Sheep raising for wool production really began in 1820, when 300 merino rams were imported into Tasmania from Capt. McArthur's flocks in New South Wales. The settlers placed their flocks on grazing lands along the Derwent and the Tamar and extended into the Midlands. The savannah country of the Midlands afforded excellent pasturage and the climate favoured the production of fine quality merino wool. In 1843 the system was started whereby prisoners were hired out to settlers on probation, at low rates of pay; this provided labour for pastoral developments, and by 1846 the ordinary leased lands from the Crown amounted to 337,000 acres. It was during this period, in 1836, that the two sons of Thomas Henty went over from the Tamar and established a settlement at Portland Bay. This was the beginnings of the foundation of Victoria, which became a separate colony in 1850. Tasmania supplied rams with high quality fleece to the Victorian graziers during these early years, which was a useful source of income for the Tasmanian sheep farmer.

(b) Second Period, 1847-1858 [2]

The rapid rise in sheep numbers during this period suggests the influence of environmental factors differing from those of the first period. These factors are

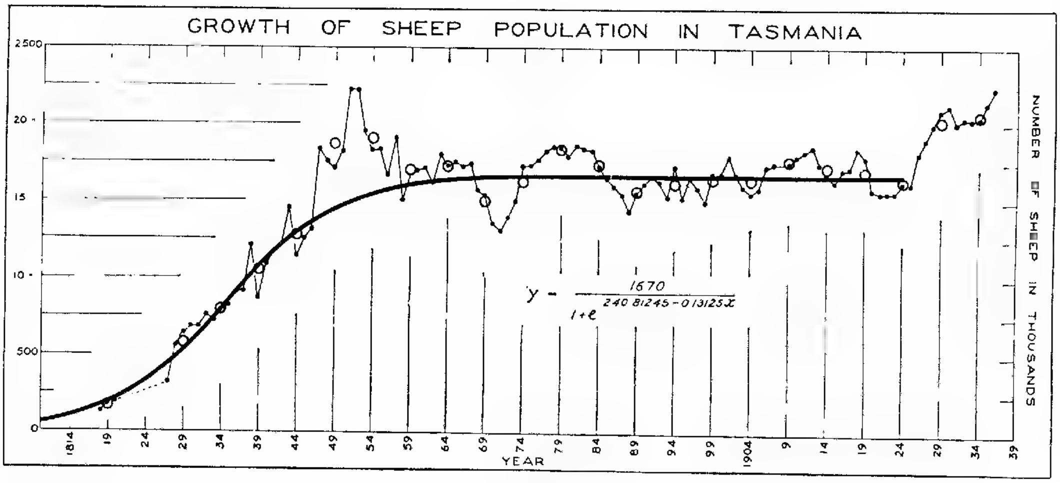

Fig. 1

Calculated growth curve for the sheep population of Tasmania. The sheep numbers obtained from official records are shown for each year (small closed circles); the average numbers for five-year periods are also shown (larger open circles).

associated primarily with a marked expansion of grazing areas and heavy stocking of sheep runs. Whyte (1871) states that, owing to the poor market for fat sheep in Tasmania, the sheep farmer concentrated on wool production and sheep runs were heavily overstocked. It appears to have been the practice of contractors to supply the meat requirements of military and prison establishments in Tasmania by importing sheep and bullocks from the mainland; the net imports of sheep during 1849-54 were 290,400. With the marked extension of grazing activities

(2) I am indebted to Professor S. M. Wadham and Professor G. L. Wood for helpful information about this period.

the area of ordinary leased Crown lands rose suddenly in 1847 to 1,063,000 acres; by 1853 the area had increased to 2,314,000 acres.

In the latter half of the period the sheep numbers decreased rapidly and finally came to rest about the calculated curve. The conditions which led to the temporary increase in sheep numbers were evidently unstable. The occupied natural pastures could not carry permanently this high density of population. This is clearly shown by the lower average level of saturation (1,670,000) which obtained for the next 70 years.

Several factors were associated with this fall in sheep numbers. The area of ordinary Crown lands held under lease decreased after 1853, and was 536,000 acres less in 1858. The sheep farmer was also learning from experience that it was more profitable to stock his pastures with proper regard for their sheep-carrying capacity; a smaller number of well nourished sheep carry more wool than a larger number of impoverished sheep on overstocked pastures.

After 1851 there was an increased demand for fat sheep in Tasmania; the importation of sheep declined from 65,089 in 1851 to 11,786 in 1858; the price of mutton in Hobart appreciated from 3d. per lb. in 1851 to 6d. in 1852 and 8½d. in 1853. These factors revived the interest of the sheep farmers in fat sheep for local markets, which would bring about a reduction in the number of sheep carried on certain pastures.

The export of rams to the mainland declined as the graziers in Victoria and the Riverina developed their own stud flocks, which considerably reduced the income available to the Tasmanian graziers from this source.

The supply of labour available for pastoral pursuits was directly affected by the discovery of gold in Victoria in 1851 and the cessation of the transportation of convicts to Tasmania in 1853.

(c) Third Period, 1859-1924

The events which occurred during the latter part of the previous period tended to produce a more stable sheep population. With the election of the first Parliament in Tasmania in 1856 the country settled down to steady development. The sheep numbers oscillate about the calculated curve throughout this period, the short-term oscillations being due to the temporary influence of various factors. The decrease in numbers about 1870 is associated with *(a)* the prevalence of sheep scab, which necessitated the passing of the "Scab Act of 1870"; *(b)* the prevalence of fluke in certain pasture areas; *(c)* the development of the rabbit pest, which necessitated the passing in 1871 of "An Act to Provide for Destruction of Rabbits in Tasmania"; *(d)* the persistent fall in the price of wool which dropped from 22d. a pound to 15d. a pound between 1862 and 1870.

(d) Fourth Period, 1925-1936

The upward trend in the population in this period is associated with the improvement in pastures and their management, together with the expansion of the market for fat lambs. The area of top-dressed pastures has steadily increased.

In 1923/4 the total agricultural area manured with artificial manures was 193,453 acres; it had increased to 412,468 acres in 1936/7 with an increase of 14,000 tons in the amount of artificial manures used. The area of top-dressed pastures increased from 52,077 acres in 1929/30 to 191,928 acres in 1936/7. Improvements of the natural pastures have increased their sheep-carrying capacity.

Corrigenda

In my previous paper (Davidson, 1938, p. 141) the sheep population at the end of 1838 should read 28,000.

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THE MOUNT CAERNARVON SERIES OF PROTEROZOIC AGE

By D. MAWSON, O.B.E., D.Sc., B.E., F.R.S.

Summary

Mount Caermarvon is the highest point of a bold range of hills which forms the eastern flank of the Flinders Range in the locality lying due east-south-east of Oraparinna Head Station. In that locality exists a large unbroken block of Proterozoic sediments. Differential weathering has there brought into strong relief the hard and soft members in the succession of strata, resulting in a series of parallel ridges marking the hard beds. Mount Caernarvon is on the crest line of the most westerly of these ridges which, as the beds dip regularly to the east, is the lowest (oldest) in order of deposition. Looking eastward from the summit of Mount Caermarvon, other parallel ridges extend athwart the view until, at a distance of about 5 miles, the low and nearly level plain leading to Lake Frome is reached.

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[Read 13 October 1938]

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Throughout a section measured across the strike of these beds, as detailed below, there was found to be a remarkable regularity in the dip of the beds and no evidence of faulting. The average dip is about 28 degrees, whilst the high and low extremes of dip recorded are, respectively, 31 and 25 degrees. The strike of the beds, where undisturbed, is about 10° east (true).

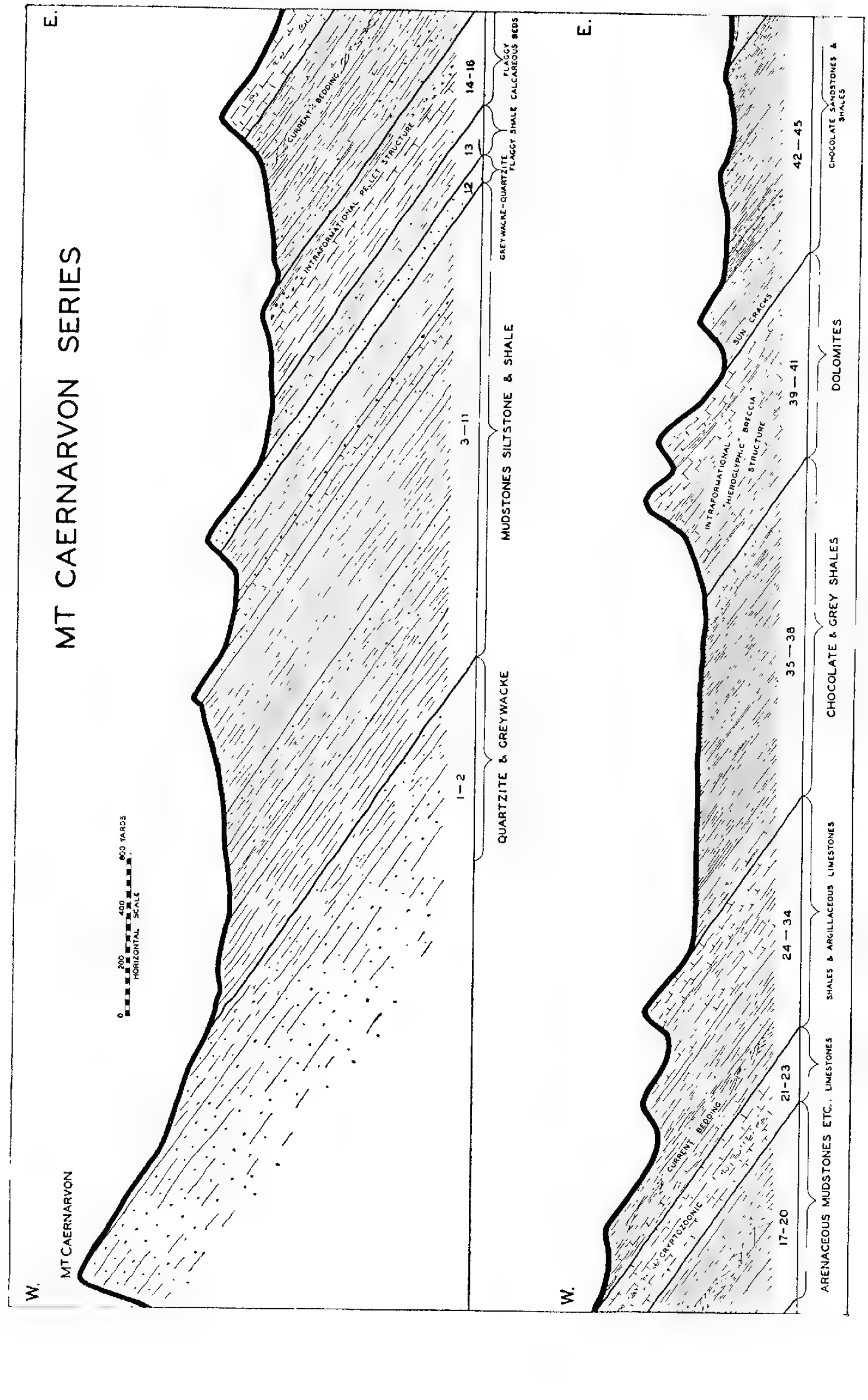
At less than 3 miles northward from the Mount the beds are faulted and twisted almost at right angles to their former alignment. To the south, the undisturbed character of the block continues only for a few miles.

In view of the favourable features presented by this block, it has been selected as an area for special study in connection with our investigations of the Pre-Cambrian succession in the Flinders Range, which is the outstanding area for Proterozoic rocks in South Australia.

In the following list of strata encountered in this section, the beds are dealt with in order, from below upwards, and the thicknesses given in feet are the reduced values of true thicknesses. The full thickness of the Mount Caernarvon greywackes at the base of the section was not ascertained for those beds extended further west than the summit of Mount Caernarvon, which was the western limit of the section. The fact that the number 1 item on the list does extend beyond the 100 feet measured is indicated in the list by the plus sign attached.

The upper limit of the section was determined by the fact that beyond the beds listed no outcrops appear near the line of section above the alluviated plain. There is, however, no reason to suppose that the sequence does not continue below the surface accumulations of the plain.

The accompanying line block illustrates the relation of the individual beds to the surface topography.


MT CAERNARVON SERIES
W.
E.
MT CAERNARVON
0 200 400 600 YARDS
HORIZONTAL SCALE
CURRENT-BEDDING
INTRAFORMATIONAL PELLET STRUCTURE
1-2
3-11
12
13
14-16
QUARTZITE & GREYWACKE
MUDSTONES SILTSTONE & SHALE
GREYWACKE-QUARTZITE
FLAGGY SHALE
FLAGGY CALCAREOUS BEDS
W.
E.
CRYPTOZOONIC
CURRENT BEDDING
INTRAFORMATIONAL "HIEROGLYPHIC" BRECCIA STRUCTURE
SUN CRACKS
17-20
21-23
24-34
35-38
39-41
42-45
ARENACEOUS MUDSTONES ETC., LIMESTONES
SHALES & ARGILLACEOUS LIMESTONES
CHOCOLATE & GREY SHALES
DOLOMITES
CHOCOLATE SANDSTONES & SHALES

SECTION EASTWARD FROM MOUNT CAERNARVON

Mount Caernarvon Greywackes

1 100 + ft. of greywacke-quartzite at the summit of Mount Caernarvon: very fine-grained, buff and grey coloured. Dip, 26° to the east.

2 154 ft. of a series of somewhat argillaceous, flaggy, greywacke sandstones and quartzite with occasional harder, more quartzose bands and, in the upper section, some sandy, flaggy slates.

614 + feet in total thickness.

Shale, Mudstone and Siltstone Series

3 413 ft. of very fine-grained, grey laminated siltstones and flag-stones; in part slightly calcareous.

4 411 ft. very thin-bedded, grey shales, somewhat calcareous, and flag-stones of a similar nature but somewhat arenaceous. Dip, 26° to the east.

5 503 ft. of massive, fine-grained, grey mudstones. Evidence of a small calcareous content.

6 29 ft. of a light-grey coloured, fine-grained greywacke-sandstone.

7 105 ft. thin-bedded shales; beds of a more sandy nature alternating with those of a more argillaceous character.

8 85 ft. thin flaggy, argillaceous shales becoming increasingly more calcareous.

9 135 ft. of dense, thick-bedded calcareous shales, including, in the upper section, a band of dolomitic limestone.

10 35 ft. of somewhat calcareous shales enclosing thin, arenaceous bands and culminating above in an 8 feet thick bed of sandstone.

11 276 ft. of thin-bedded, hard, grey shales with occasional intercalations of thin, arenaceous bands.

1,992 feet in total thickness.

Greywacke-Quartzite

12 220 ft. of light-grey, evenly-grained, greywacke-quartzite, constituting a ridge line in the local topography.

220 feet in total thickness.

Flaggy Shales

13 438 ft. of flaggy shales, somewhat calcareous; for the most part thin-bedded. Dip, 31° to the east.

438 feet in total thickness.

Flaggy, Calcareous Beds

14 236 ft. of flaggy, impure limestones.

15 73 ft. of a dolomitic limestone series, for the most part flaggy.

16 147 ft. of flaggy, calcareous beds. Near the base, this section is composed of thick-bedded, dense, somewhat calcareous shales with occasional richly-calcareous bands. The upper division is in part a fine-grained, argillaceous, conglomeratic, pellet limestone of unique character, the latter a kind of intraformational conglomerate.

456 feet in total thickness.

Arenaceous Mudstones, etc.

17 137 ft. of grey, calcareo- argillaceous mudstones which, at several horizons, become notably arenaceous. Shallow-water phenomena evidenced.

18 299 ft. of a light-grey sandstone in the lower section, composed of rounded grains. Upwards, this passes into blue-grey shales with sandy bands recurring at intervals. A shallow-water formation, current-bedded.

19 15 ft. of chocolate-coloured shales, somewhat calcareous.

20 284 ft. of grey mudstones with some richly arenaceous bands. Somewhat calcareous throughout and increasingly so towards the upper limit. Flaggy below, but massive above.

735 feet in total thickness.

Limestones

21 110 ft. of massive, impure limestones. Dip, 30° to the east.

22 289 ft. of massive, impure limestones, in part cryptozöonic.

23 183 ft. of massive, sandy, shallow-water limestones.

582 feet in total thickness.

Shales and Argillaceous Limestones

24 62 ft. of calcareous shales.

25 139 ft. of impure limestones with shallow-water features.

26 124 ft. of grey shales.

27 220 ft. of impure limestones; massive below and flaggy above.

28 300 ft. of chocolate-coloured shales and grey shales.

29 161 ft. of calcareous flagstones. Dip, 28° to the east.

30 146 ft. of impure dolomitic limestone with shallow-water features.

31 155 ft. of shales, mainly chocolate-coloured, with some thin calcareous bands.

32 15 ft. of impure limestones of a somewhat purple colour.

33 180 ft. of shales.

34 108 ft. of impure limestone.

1,610 feet in total thickness.

Chocolate and Grey Shales

35 395 ft. of grey and chocolate-coloured shales, weathering at the surface into small chips. Capped by a bed of buff-coloured dolomite 2 feet thick.

36 223 ft. of chocolate shales, weathering to chips on the surface. Inter-bedded are several seams, 2 to 3 inches thick, of limestone.

37 989 ft. of grey shales, breaking down to fine chips on exposure at the surface. At the upper limit are several inter-bedded, thin (up to 6 inches thick) seams of dolomite. Dip, 29° to the east.

38 120 ft. of shales with dolomitic bands increasing in number and thickness towards the top.

1,727 feet in total thickness.

Dolomite (hieroglyphic) Series

39 319 ft. of dolomitic beds. Bands of chocolate-coloured dolomite alternating with softer beds of flaggy chocolate shales. Most of the dolomite bands exhibit a very remarkable and characteristic "hieroglyphic" structure.

40 291 ft. of a dolomite series with softer, shaley partings. Some of the dolomite beds exhibit "hieroglyphic" markings, others feature a thin laminated (2 mm. thick) texture.

41 291 ft. of beds composed of massive, buff-coloured dolomite below, becoming more friable and chocolate-coloured and impure above. Some "hieroglyphic" markings in this division.

901 feet in total thickness.

Chocolate Sandstone and Shales (Tuffaceous ?)

42 238 ft. of sun-cracked, chocolate shales.

43 148 ft. of beds, mainly reddish-coloured sandstones.

44 550 ft. of a chocolate-coloured series, chiefly shales with some thin beds of sandstone, mainly near the base. The nature of some of the sandy bands suggests water-sorted tuffs. A 10-feet thick band of sandstone forms the top of this section.

45 500 ft. of chocolate-coloured beds. This division is largely hidden beneath soil but appears to be mainly chocolate shales. At 30 feet from the base there are intercalations of thin (½ to 5 inches thick) bands of dolomite. The upper 100 feet is reddish-chocolate-coloured and becoming increasingly sandy above, finalising in thin-bedded, sandy flagstones. Dip, 29° to the east.

1,436 feet in total thickness.

These beds all lie at a lower stratigraphical level than those detailed in a recent paper(1) dealing with formations existing some 25 miles to the north-west of Mount Caernarvon. No attempt will be made in this place to relate these formations to those of the Parachilna locality or to discuss their significance, for such will come better at a later stage when the details of further critical areas under review are published. It may be mentioned, however, that the deposition of the lowest beds in this section was contemporaneous with some part of the time occupied in the laying down of glacial and fluvio-glacial sediments in other parts of South Australia.

The nature of the cryptozöonic and "hieroglyphic" markings of the dolomitic limestones will be dealt with elsewhere.

The 10,711 feet of strata accounted in this contribution represents only a portion of the depositions laid down in the Flinders Range geosyncline during late Proterozoic time.

(1) "Cambrian and Sub-Cambrian Formations at Parachilna Gorge." Proc. Roy. Soc. S. Aust., July, 1938.

ADDITIONS TO THE FLORA OF SOUTH AUSTRALIAN [1] NO. 37

By J. M. BLACK, A.L.S.

Summary

SALVINIACEAE

Azolla filiculoides, L. var. *rubra* (R. Br.) Diels. In water at Glencoe, S.E.; July, 1938; *E. S. Alcock*. A new locality.

ADDITIONS TO THE FLORA OF SOUTH AUSTRALIA (1)

No. 37

By J. M. Black, A.L.S.

[Read 13 October 1938]

Plate XX

Salviniaceae

Azolla filiculoides, L. var. *rubra* (R. Br.) Diels. In water at Glencoe, S.E.; July, 1938; *E. S. Alcock.* A new locality.

Gramineae

Perotis indica (L.) O. Kuntze (1891). Macdonald Downs, C.A., March, 1936; *Miss Jean Chalmers.*—*Anthoxanthum indicum,* L. (1753); *Perotis latifolia,* Ait. (1789); *P. rara,* R. Br. (1810).

In our specimens the spikelets, including the awns, are only 15-18 mm. long; the leaf-blades are 3-4 mm. broad.

Sporobolus pulchellus, R. Br. Macdonald Downs, March, 1936, *Miss Jean Chalmers.* First record for Central Australia.

Brachiaria Gilesii (Benth.), Chase. Macdonald Downs, C.A., March, 1936; *Miss Jean Chalmers.*

Our specimen is about 20 cm. high and the two terminal spikes (or panicle-branches) are exserted, sometimes for a considerable distance, from the sheath of the uppermost leaf.

Enneapogon pallidus (R. Br.) Beauv. = *Pappophorum pallidum,* R. Br.; *P. nigricans,* R. Br. var. *pallidum,* Domin.

South Australia—Finniss Springs, near Lake Eyre, December, 1926; Kulpi, near Musgrave Ranges, January, 1934, *H. H. Finlayson;* Alberga Creek, July, 1920, *H. W. Andrew.*

Central Australia—Macdonald Downs Stations, March, 1936, *Miss Jean Chalmers.*

Domin recorded it in 1915 for Northern Australia, Queensland, and South Australia.

A grass 8-30 cm. high, the leaves and outer glumes with rather long spreading hairs; panicles pale-coloured, dense, cylindrical, 4-6 cm. long; first outer glume 5 mm. long, 7-9-nerved; second 6 mm. long, 7-nerved.

Enneapogon, Desv., differs from *Pappophorum,* Schreb., in having always more than 1-nerved outer glumes and constantly 9 awns at the summit of the flowering glume.

(1) Some records of Central Australian species, collected by recent travellers, have been included.

Iseilema

The discovery by C. E. Hubbard that *Anthistiria membranacea,* Lindl. (1848) is the same as *Iseilema actinostachys,* Domin (1915), necessitates the following changes in the naming of our species as published in Trans. Roy. Soc. S. Aust., **57**: 143 (1933).

1 *I. eremaeum,* S. T. Blake in Proc. Roy. Soc. Qld., **49**: 82 (1938) = *I membranacea,* J. M. Black in Trans. Roy. Soc. S. Aust., **57**: 143 (1933), not *Anthistiria membranacea.* Lindl. Awn 12-15 mm. long (not 20 mm.). The racemes are finally exserted from the floral leaf-sheaths (or involucral bracts) almost as much as in the next species.

South Australia—Far north. Queensland—As far west as Birdsville.

2 *I. membranaceum* (Lindl.) Domin (only as to the name, not the description) = *Anthistiria membranacea,* Lindl. and *I. actinostachys,* Domin.

3 *I. vaginiflorum,* Domin. Awn, 16-23 mm. long.

There are now 11 described species of *Iseilema,* of which three have so far been found in South Australia.

Zoisia Matrella (L.) Merrill (= *Z. pungens,* Willd.) This small grass, resembling *Distichlis spicata,* and collected by Prof. J. B. Cleland in damp places near the Rocky River and Karatta, Kangaroo Island, has been provisionally determined as above by Mr. C. E. Hubbard, of Kew.—Coasts of Malaya, South India, China, and the Philippines. Spikes about 1 cm. long; spikelets 2½-3 mm. long.

The larger species, found in the eastern States of Australia, is *Z. macrantha,* Desv. Spikes 2½-5 cm. long; spikelets 3½-5 mm. long.

Orchidaceae

Orthoceras strictum, R. Br. Vivonne Bay, December, 1934, *J. B. Cleland.* First record for Kangaroo Island.

Centrolepidaceae

Centrolepis glabra (F. v. M.), Hieron. Swamp at mouth of South-West River, Kangaroo Island, December, 1934; *J. B. Cleland.* Some of the smaller specimens (1-2 cm. high) have only three flowers in each head, with 4-5 carpels.

Polygonaceae

Polygonum prostratum, R. Br. Edge of swamp at mouth of South-West River, Kangaroo Island, December, 1934; *J. B. Cleland.* "Quite prostrate." First record for the island. Leaves smaller than usual, only 5-12 mm. long; racemes denser, shorter, broader.

Caryophyllaceae

Stellaria filiformis (Benth.), Mattf. in Fedde Repert., Beiheft C, 148, t. vii, figs. 1-8 (1938), instead of *Drymaria filiformis,* Benth. The change is made by J. Mattfeld, on the ground that this plant has the characters of *Stellaria* (3 free styles, a 6-valved cylindrical capsule and no stipules), whereas *Drymaria,* which is almost entirely an American genus, has a single style surmounted by three branches, a capsule usually ovoid or globular and opening in three valves, and stipules.

This very slender little plant has only been found on the Murray and near Ardrossan, Yorke Peninsula, in South Australia, and appears to be very rare, but may have been overlooked on account of its insignificance. It is found throughout temperate Australia.

CRUCIFERAE

Lepidium halmaturinum nov. sp. Planta annua, fere glabra; caules tenues, plus minusve ramosi; folia inferiora lyrato-pinnatipartita, petiolata, 2-5 cm. longa, lobis dentatis, sparse ciliolatis, terminali ovato, 5-20 mm. longo, lateralibus 3-7, multo minoribus; folia superiora oblongo-cuneata, in petiolum brevem angustata, 5-20 cm. longa, 3-7- dentata; racemi fructiferi 3-5 cm. longi, pedicellis directi-angule patentibus, 2-4 mm. longis; sepala cymbiformia, $\frac{3}{4}$ mm. longa; petala alba, perminuta vel nulla; stamina 2; silicula ovata, 3 mm. longa, $2\frac{1}{2}$ mm. lata, breviter emarginata, incisurâ stigma sessile parum superante; semina mucosa. (Pl. xx, fig. 1.)

Ravine des Casoars, Kangaroo Island, December, 1934, *J. B. Cleland.*

Nearest to *L. pseudo-ruderale,* Thell., but differs in its stems shorter and more slender, its lower leaves lyrate, with the lateral lobes very short and the upper leaves cuneate; also in the pedicels spreading at right angles to the peduncles. The locality is also quite different.

Cardamine hirsuta, L. Ravine des Casoars, Kangaroo Island; December, 1934; *J. B. Cleland.* Very small specimens. First record for the island.

LEGUMINOSAE

Cassia curvistyla nov. sp. Suffrutex humilis, 10-45 cm. altus, omnino breviter pubescens; folia 2-3 cm. longa, stipulis linearibus, persistentibus; foliola 6, raro 4, lanceolato-oblonga, plana, mucronulata, 8-16 mm. longa, 3-4 mm. lata, glandulâ inter quidque par subulatâ; flores bini trini vel solitarii ad apicem pedunculorum axillarium folia subaequantium, bracteâ lineari pedicello fere aequilongâ, caducâ; sepala 2-3 mm. longa, obtusa; petala flava, sepala parum superantia; stamina 10, omnia perfecta, septem $1\frac{1}{2}$-2 mm. longa, tria minora; ovarium pubescens, stylo brevi, crasso, curvo; legumen immaturum breviter stipitatum, planum, tenue, puberulum, septatum, circa 3 cm. longum et 1 cm. latum; semina 3-6, transversa. (Pl. xx, fig. 2.)

Central Australia—20 miles south of the Granites, August, 1936, *J. B. Cleland;* west of Mount Davenport, Treuer Range, 1938, *Ben Nicker.*

Belongs to section *Psilorhegma,* and seems nearest to *C. Chatelainiana,* Gaudich, but that species is glabrous, has 6-10 larger leaflets, has the subulate gland only between the lowest or two lowest pairs and has larger flowers.

Cassia concinna, Benth. On sandhills near Mount Cockburn (between the Treuer and Ehrenberg Ranges, C.A., 1938, *Ben. Nicker.*

Pultenaea trifida, J. M. Black. North end of Flinders Chase, Kangaroo Island, December, 1934, *J. B. Cleland.* The bracteoles are sometimes bifid instead of trifid, one of the two lateral lobes apparently aborting.

Sapindaceae

Diplopeltis Stuartii, F. v. M. South-east of Thomson's Rockhole, Central Australia, August, 1936, *J. B. Cleland;* west of Mount Davenport, Treuer Range, C.A., 1938, *Ben. Nicker,* "18 inches (45 cm.) high, on burnt spinifex sand plain."

Thymeleaceae

Pimelea dichotoma, Schlechtd., in Linnaea 20: 581 (1847). Flowers white; leaves coriaceous, often spreading, 4-8 mm. long.—*P. parvifolia,* Meisn. in Linnaea 26: 345 (1853); *P. diosmifolia,* A. Cunn. ex D. C. Prodr. 14: 510 (1857), non Lodd. Bot. Cab. t. 1708 (1831); *P. flava,* R. Br. var. *diosmifolia,* Meisn., in Mohl et Schlechtd. Bot. Zeit., 1848, p. 396.

Along most of our coastline and on the Adelaide foothills and in the Murray lands. It is distinguishable from the following species, both in the field and the herbarium.

P. flava, R. Br. Prodr. 361 (1810). Flowers yellow; branches more erect; leaves thinner, 6-14 mm. long.

Collected in our State only on Kangaroo Island, near Vivonne Bay.—Eastern States and Tasmania.

Epacridaceae

Acrotriche fasciculiflora, Benth. Breakneck River, Kangaroo Island, March, 1919; Bull's Creek, Flinders Chase, Kangaroo Island, December, 1934; *J. B. Cleland.* The Kangaroo Island specimens appear to have the fruiting clusters less numerous and the sepals more hairy than those of the mainland.

Umbelliferae

Hydrocotyle comocarpa, F. v. M. Ravine des Casoars, Kangaroo Island, December, 1934, *J. B. Cleland.*

Borraginaceae

Halgania erecta, Ewart et Rees in Proc. Roy. Soc. Vic., n.s., 23: 58, t. 12 (1910).

Central Australia—On sandhills 60 miles north of Kintore Range, Central Australia, 1938, *Ben. Nicker.* First record for Central Australia. The type-specimen was collected by R. Helms in the Victoria Desert, Western Australia, Camp 38, September, 1891.

H. solanacea, F. v. M. 60 miles north of Kintore Range, C.A., 1938 *B. Nicker.*

Rubiaceae

Asperula euryphylla var. *tetraphylla*, Shaw et Turrill. Rocky River, Kangaroo Island; between Kingscote and Vivonne Bay, Kangaroo Island, 1924 and 1934, *J. B. Cleland*. Only found so far on Kangaroo Island. The type, with 6-leaved whorls, is Victorian. (Pl. xx, fig. 3.)

**Galium divaricatum*, Lamk. Vivonne Bay, Kangaroo Island, December, 1934, *J. B. Cleland*. First record for Kangaroo Island.

Campanulaceae

Wahlenbergia quadrifida (R. Br.), A. DC. Rocky River, Kangaroo Island, December, 1934, *J. B. Cleland*.

W. multicaulis, Benth. Rocky River, Kangaroo Island, December, 1934, *J. B. Cleland*. Small specimens with mostly simple stems. New records for the island.

Goodeniaceae

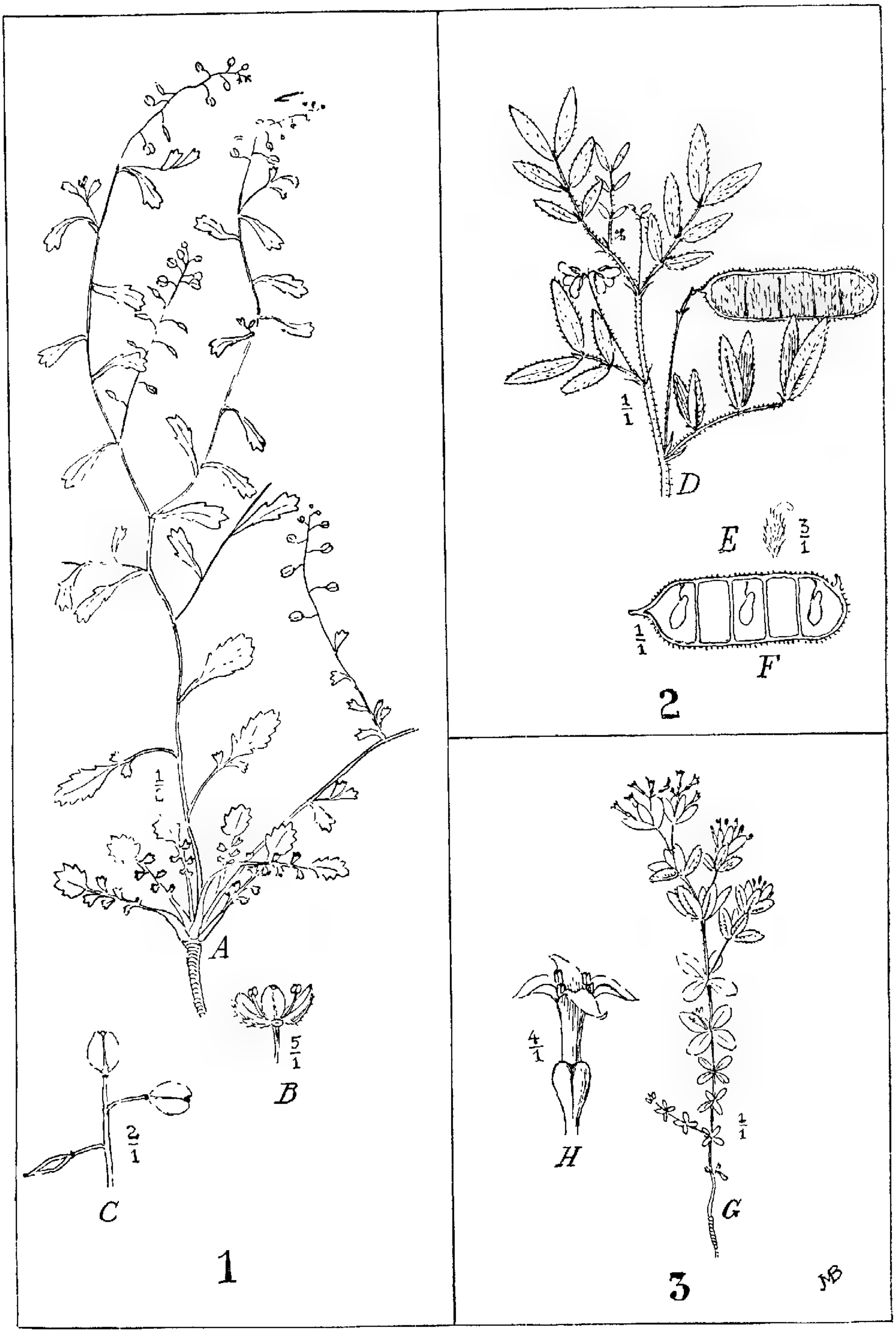
Goodenia azurea, F. v. M. About 50 miles north-east of Kintore Range, Central Australia, 1938, *B. Nicker*. "Grows on stony ridges." Also collected 35 miles north-west of Lander Creek in 1911 by G. F. Hill.

DESCRIPTION OF PLATE XX

Fig. 1 *Lepidium kalmaturinum*:—*A*, the plant; *B*, flower with two sepals removed; *C*, summit of fruiting branch.

Fig. 2 *Cassia curvistyla*:—*D*, flowering and fruiting branch; *E*, ovary and style; *F*, one valve of pod.

Fig. 3 *Asperula euryphylla* var *tetraphylla*:—*G*, the plant; *H*, corolla and ovary.



1 *Lepidium halmaturinum.* 2 *Cassia curvistyla.* 3 *Asperula euryphylla* var. *tetraphylla.*

THE RADIO-ACTIVITY AND COMPOSITION OF THE WATER AND GASES OF THE PARALANA HOT SPRING

By KERR GRANT, M.Sc.

Summary

The general and geological features of the Paralana Hot Spring, which is situated on the eastern side of the Flinders Range about 400 miles north-east of Adelaide, have already been described in a paper presented by Sir Douglas Mawson to the Royal Society of South Australia (Proc. Roy. Soc. of S. Aust., 51, 391, 1927). The present paper reports only the results of observations on its radio-activity and gaseous content. These observations were made, in the first place at the spring, by an expedition consisting of the writer (K. G.) and Messrs. Iliffe and Thompson, members of the staff of the physics department of Adelaide University, which visited the spring in May of this year, and, subsequently, in the physics laboratory of Adelaide University, upon samples of gas and water collected at the spring and brought back for further examination.

THE RADIO-ACTIVITY AND COMPOSITION OF THE WATER AND GASES OF THE PARALANA HOT SPRING

By Kerr Grant, M.Sc.

[Read 13 October 1938]

Plate XXI

The general and geological features of the Paralana Hot Spring, which is situated on the eastern side of the Flinders Range about 400 miles north-east of Adelaide, have already been described in a paper presented by Sir Douglas Mawson to the Royal Society of South Australia (Proc. Roy. Soc. of S. Aust., **51**, 391, 1927). The present paper reports only the results of observations on its radio-activity and gaseous content. These observations were made, in the first place at the spring, by an expedition consisting of the writer (K. G.) and Messrs. Iliffe and Thompson, members of the staff of the physics department of Adelaide University, which visited the spring in May of this year, and, subsequently, in the physics laboratory of Adelaide University, upon samples of gas and water collected at the spring and brought back for further examination.

The expedition left Adelaide by car on the afternoon of Monday, 23 May, 1938, and arrived at the old and now abandoned homestead of the Paralana Sheep Station on Thursday, 27 May. The next three days were spent in collecting samples of gas and water from the spring, which is about 2½ miles distant from the homestead, and in making such observations as were possible on the spot with apparatus which had been brought for that purpose. This apparatus included two electroscopes, each mounted on an ionisation-chamber with necessary apparatus required for measurement of the amount of radium emanation contained in the spring water (*vide* Appendix), and a Geiger-Muller electron-tube counter which could be used for the detection of feeble sources of radio-activity by means of their gamma ray activity.

As described by Mawson, the gas rises in a fairly continuous stream of bubbles from a number of points, perhaps twelve or more in all, in the sandy bottom of the pool. These points appear to be fairly definite in location, though the escape of gas from any one may cease for a time and resume after an interval which may range from a few seconds to several minutes. The gas was collected in screw-top bottles by the usual device, namely, by inverting a wide-mouthed tin funnel under water over the point from which the stream of bubbles issues and inserting the upward-pointing neck of the funnel into the neck of a bottle which had been previously filled with the spring water, the bottle being also supported in an inverted position. The gas-bubbles entering the bottle gradually displace the water, and when the bottle is nearly but not quite filled with gas, it is lifted from the funnel and the screw-top inserted without permitting the mouth of the bottle to rise above the surface of the water. The bottle is kept and carried always in an inverted position, so that it is continually water-sealed. Even without the water-seal there is no reason to think that any appreciable amount of gas would enter or leave a bottle in which the top is screwed tightly home and, with the water-seal, such escape is certainly impossible. These bottles had a capacity of approximately one and one-third pints (760 c.c.) and the time taken for a bottle to fill from a single stream of gas-bubbles was approximately half-an-hour, though very variable. Assuming that twelve vents had this same productivity we get a daily (24-hour) output of gas of the order of twenty cubic feet per day. It is possible, of course, that this output might be very greatly increased by cleaning out the sand from the bottom of the pool and removing the huge rocks which have fallen into it from the overhanging cliff. Judging by the sound of bubbling, there was an issue of gas from a vent beneath the largest of these rocks with an output larger than any of those in the open pools.

Radio-activity had previously been reported in the gas, though not in the water, of the pool by Dr. C. Fenton, and confirmed by Mr. R. G. Thomas in a sample sent by Dr. Fenton to Adelaide. The strength and character of the radio-activity have not previously been definitely determined. Tested at the Paralana homestead on the evening after collecting, the bottles of the gas showed strong, those of the water much weaker but still definite radio-activity. The Geiger-Muller tube counter was used for this first test. This instrument, which counts the individual electrons liberated within the counting tube by gamma-radiation passing through it, the number of these electrons liberated per second being proportional to the strength of the gamma-rays, has always a natural or background count which has to be subtracted from the total count when a radioactive source of gamma-rays is placed near the tube to give a figure determinative for this latter.

This background count is due partly to the slight radio-activity always present in the earth, in the air, and in the metal and other materials of tube and accessory apparatus, partly to electrons liberated by cosmic rays. The count must always be taken over a considerable interval of time in order to reduce the variations due to statistical fluctuations in the strength of the radiations. On a count of 100 this fluctuation averages ten per cent., on 10,000 one per cent., etc. Only when the count exceeds the background by a fraction definitely in excess of these values can sound inference of the presence of radio-activity be made.

The background count of the counting-tube used on this trip was determined in the physics laboratory and found to lie between 10 and 20 per minute; that in the old Paralana homestead lay within the same range, though possibly somewhat higher than in Adelaide. The count at the spring itself, however, was unmistakably higher, possibly three or four times as high. This high activity was probably due to the continuous escape of radon from the spring and the deposit of the products of its disintegration on the surrounding rocks, trees, etc. When a bottle of gas from the spring was held within a foot of the counting-tube the counts were invariably increased to a figure exceeding this background by more than fifty per cent. The approximation of a bottle filled with the spring-water to the same distance gave a smaller but still definitely significant increase in the count. The radio-activity of the water thus put in evidence was such as might be expected to result from radon gas (radium emanation) dissolved in the water in consequence of the active gas bubbling through it. More accurate measurements made next day at the spring indicated an activity in the water of 1,050 "Eman" units per litre (one "Eman" unit is 10^{-10} curie); in the gas of 7,800 "Emans" per litre.

An attempt was made to separate out any helium gas, which the spring gas might contain, from the nitrogen and other common gases on the spot, by heating the gas in contact with metallic calcium contained in a silica tube, a procedure which has been successfully used for the purification of radon at the Adelaide University. The attempt failed because it was found impossible in the open air to heat the tube and its contained calcium with a plumber's blow-lamp—the only means available—to the temperature (600° C. or higher) at which it will combine with nitrogen to form the nitride.

On return to Adelaide, Mr. Thompson undertook a series of systematic measurements on the radio-activity of the gas dissolved in the water with a view to ascertaining the rate of decay of its radio-activity, from which rate the nature of the active constituent could be inferred. The measurements were made with an ionisation-chamber combined with an electroscope. The apparatus was standardised, in order to reduce these measurements to absolute value, by means of solutions prepared from standardised tubes of radium chloride solution supplied to the writer by the Physikalische Technische Reichsanstalt, Charlottenburg, Germany. The results of these measurements are as under:

Time (Day and Hour)	Activity (in Arbitrary Units)
2320 - 7.6.38	262
1003 - 8.6.38	240
1402 - 8.6.38	236
1737 - 8.6.38	226
1104 - 9.6.38	202
1615 - 9.6.38	185
1142 - 10.6.38	168

If the alpha-ray activity—which is what is measured by the method employed—is due only to a single species of radio-active element, then the law of radio-active decay with time is exponential, *i.e.*, the activity decays by the same fraction in the same time—and the plot of the logarithm of the activity against the time is a straight line.

As the graph of Fig. 1 shows, this relation is obeyed very closely by the measurements here recorded. The slope of this graph gives the so-called "half-period" of the radio-active element in question, and this half-period as obtained from the graph is 3·82 days, agreeing very well with the accepted value 3·825 days for radon (radium emanation). This close agreement makes it improbable that any active element other than those belonging to the radium series occurs in the spring water. Nevertheless, the extrapolation of the graph back to the time at which the observation was made on the water at the spring would give an activity considerably less (by over 20 per cent.) than the value actually obtained there, and this discrepancy could conceivably be attributed to the presence of the short-lived thorium emanation. It is much more likely, however, that it arises merely from variability in the radon content of water drawn from different places in the pool and at different times, and hence there is little risk in assuming that the only active constituent of the spring water is radium emanation and that this is present to the extent of approximately 1,000 Eman units per litre of water.

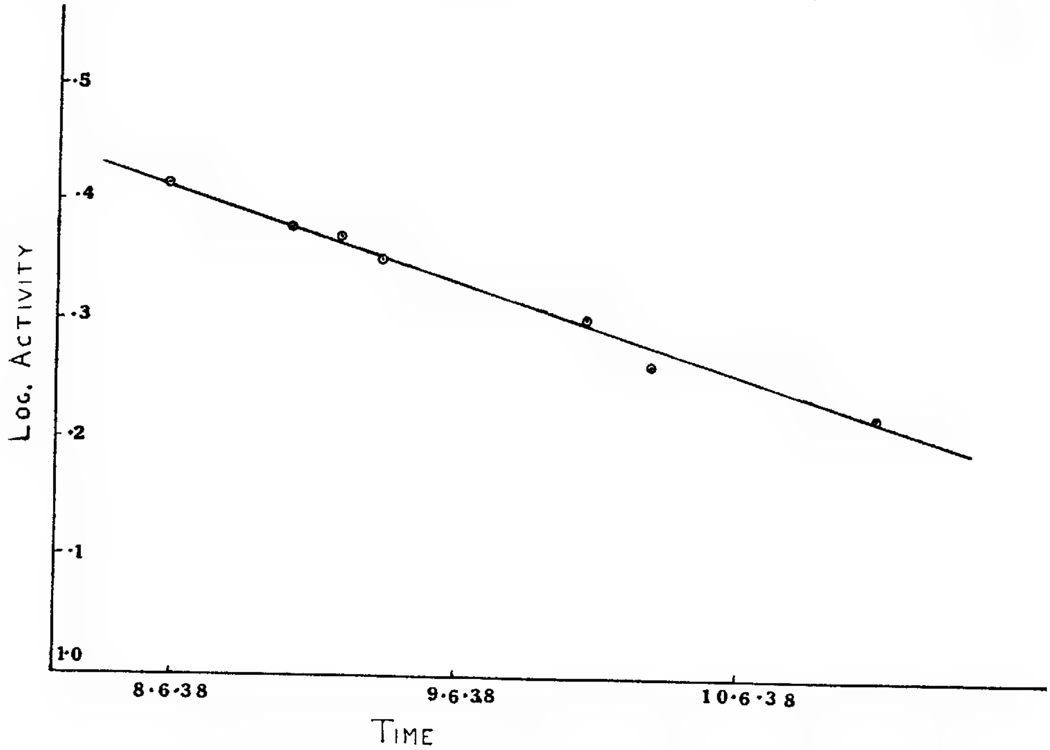


Fig. 1

The graph shows the relation between the activity of the gas contained in the water of the spring and the time. The logarithm of the activity is plotted (on an arbitrary scale) in order to exhibit, from the strictly linear character of the graph, the law of geometrical decay (*i.e.*, that the activity decreases in the same ratio in equal intervals of time) characteristic of a single species of radio-active element. The slope of the graph indicates that the activity is reduced to one-half (logarithm by 0·30) in 3·82 days, this value agreeing satisfactorily with the accepted value of 3·825 days for radon gas (radium emanation).

Although the waters of most thermal springs, in which, presumably, the water has ascended from considerable depths, contain more or less dissolved emanation, few contain so much as the Paralana Spring. In a list of fifty European Spa-waters given by Professor Stefan Meyer in his authoritative work on Radio-activity, there are only seven of which the radio-activity exceeds a value of 1,000 Emans per litre. This unusually high radio-activity of the Paralana Spring is probably not unconnected with the fact that in the rocks of the area in which the spring is situated there are frequent occurrences of uranium-bearing minerals.

The Nature of the Spring Gases

No complete analysis of the gas which bubbles up through the spring appears to have hitherto been made. The most usual constituents of gases collected from bore waters in Australia are nitrogen, carbon-dioxide, methane, hydrogen and oxygen, with the first of these usually greatly exceeding all the others.

The Department of Chemistry of the South Australian Government very kindly undertook to make an analysis for these gases, the result of which is as follows: Nitrogen, 88·1%; carbon-dioxide, 11·9%.

Since, however, the inert gas, helium, commonly, and, in lesser quantity, its congener, neon, occasionally, are found in the gases associated with thermal springs, and since in this case the probable occurrence of helium is also indicated by the radio-activity of the spring—for alpha-rays are nothing but electrically charged helium atoms—an analysis for helium or other inert gas was undertaken in the physics laboratory.

The problem to be solved in this analysis is to get rid of all gases other than the inert by chemical action or absorption. After trying with very little success three different modifications of a method involving the passage of electrical discharge between electrodes of magnesium in the vessel containing the gas the method first described by Soddy (Proc. Roy. Soc., London), viz., by heating metallic calcium in a pyrex or silica tube was resorted to. The calcium combines with the nitrogen at temperatures above 600° C., with the hydrogen at about 250°. This method proved very successful, although to obtain a complete "clean-up" of all active gases, and especially of the hydrogen, it was found advantageous to supplement the calcium process by absorption in charcoal cooled with liquid air.

The apparatus and details of procedure employed in this analysis are more fully described in the Appendix. After the "clean-up" was accomplished the residual gas was forced into a small glass capillary fitted with electrodes and the spectrum produced by an electric discharge between these examined, in the first place usually with a direct-vision spectroscope, and subsequently by photography, using a larger spectroscope and camera (pl. xxi).

Provided complete clean-up had been accomplished, not a single line could be seen in the spectrum other than those characteristic of helium; with a less perfect clean-up, hydrogen, especially the strong red line ($H\alpha$), was seen to be present and, at a still earlier stage of the cleaning-up process, the bands of nitrogen were also in evidence. Only on one of the many spectra examined could any lines be seen which, though very faint, might possibly indicate the presence of a trace of neon. If present at all in the spring gases, the percentage is less than one-hundredth of one per cent, and such an amount might well be due to contamination of the sample by atmospheric air.

Precise measurement of the percentage of helium was not easy because of its very small amount—the volume extracted from 200 c.c. being little more than one-tenth of a cubic centimetre. Three separate determinations made with the gas collected in the 4-gallon iron drum gave the following values: ·067, ·053, ·047, with a mean, therefore, of 0·056 per cent.

Mineral Content of Spring Water

An analysis of the water for its mineral content has been made by the Assay Department of the School of Mines. The results are as given in the table, in which, for the sake of comparison, the figures given for the analysis reported in Mawson's paper are also given.

	Grains per Gallon (Present)	Mawson (1927)
Chlorine, Cl	23·26	22·83
Sulphuric acid (radicle), SO^4	10·41	10·67
Carbonic acid (radicle), CO^3	9·90	9·30
Nitric acid (radicle), NO^3	nil	—
Sodium, Na	19·44	21·50
Potassium, K	2·14	2·35
Calcium, Ca	3·43	3·29
Magnesium, Mg	1·59	·19
Silica, SiO^2	4·60	5·60
Total saline matter, grains per gallon	74·77	75·73
" " " ounces per gallon	0·17	0·17

It will be seen that the only significant difference in the two analyses is in respect of the magnesium, and even this is little more than one grain in the gallon.

Since the above analysis was confined to salts of the alkali and alkaline earth metals and small quantities of the heavy metal might possibly have been present—though improbably, because the presence of hydrogen sulphide which would have precipitated these as sulphides was perceptible by its odour—I asked Dr. Allan Walkley, of the Waite Institute, who has recently been using the "Polarograph" method of detecting zinc, copper, and other heavy metals in solution, if he would be so good as to examine the Paralana water by this method. This he has done and his report on the analysis is as follows:

"Residue on evaporation	0·11%
Chlorides	0·03%
pH (glass electrode)	6·8
Copper, zinc, nickel, cobalt, iron and manganese	— less than 1 p.p.m.
Bismuth, lead cadmium	— less than 3 p.p.m.

The brown precipitate present in the original sample was not examined. The average figures for the heavy metals in 3 Bohemian spas, Marienbad, Karlsbad and Joachimsthal are, in Y per litre.

Cu	Bi	Pb	Zn	Ni
0·2–30	0·2–0·6	0·1–1	0·7–65	0·02–8."

It will be seen that Dr. Walkley's determination of the total solid dissolved, *viz.*, 0·1. per cent., agrees perfectly with that made in the assay department of the School of Mines, and that the total amount of all heavy metals from iron and zinc onwards amounts to less than four parts per million, a practically negligible content.

The temperature of the water in the spring pool was given by Mawson as 144° F. Numerous measurements made at different places in the spring by the present party gave values as a rule much below this figure, but varying from place to place, and especially with the depth to which the thermometer bulb was immersed in the water or underlying sand. The highest temperature (140° F.) was recorded in the sand beneath the large overhanging rock underneath which the outflow of water and gas seemed to be greatest.

The depth of sand in and surrounding the open pool and the dense growth of bulrushes in the creek below it rendered quite hopeless the intention of measuring the amount of water issuing. Our opinion was that the amount issuing in the open pool was today probably much less than the figure given by Mawson, *viz.*, 1,000 gallons per hour. The apparent diminution may well be due to the decrease in size of the open pool which Mawson gives as 20 yards but which is now not more than 5, so that the majority of the vents and fissures in the bed-rock by which water and gas issued in 1927 are today covered by sand and debris.

Acknowledgment

The expenses of the expedition to Paralana were met by the Paralana Hot Spring Syndicate, Melbourne.

I also acknowledge the valuable assistance I have received from Messrs. M. Iliffe and A. H. Thompson, members of my staff; Mr. H. R. Oliphant, technician of the Physics Department; also Mr. Dalwood, chief assayer at the School of Mines; Mr. Chapman, Government Analyst; and Dr. Walkley, of the Waite Institute, for assistance given in making analyses of the gas and water.

Lastly, I tender my warmest thanks to Mr. and Mrs. J. Goss, of Wooltana Station, who offered generous hospitality to the party on their journey to Paralana.

APPENDIX

Method and Results of Measurement of Radio-activity of Spring Water and Gas

The α-ray activity of samples of water and gas from the spring were measured with an ionization chamber and gold leaf electroscope.

Apparatus

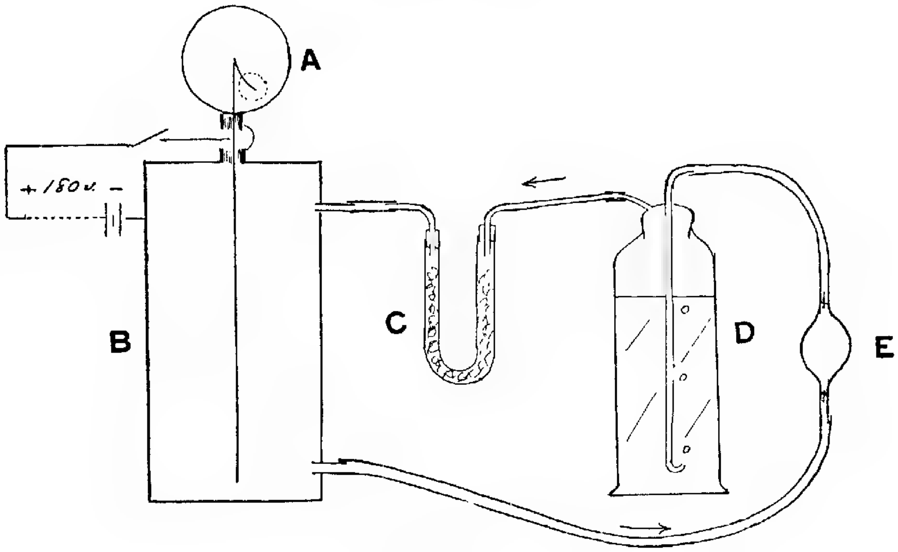


Fig. 2

The electroscope A consists of a small brass cylinder, the gold leaf being attached to a polished brass support projecting into the interior of the cylinder and insulated from it by a sulphur bushing. The ends of the cylinder are provided with two small glass windows for observation. The electroscope is supported immediately above the ionization chamber B, a large well-sealed tin having a central rod insulated from it by a sulphur bushing and provided with two side tubes for the circulation of gas through the chamber. C is a calcium chloride drying tube, D a glass "bubbler" and E a rubber bulb provided with valves allowing gas to pass in one direction only.

Procedure

100 c.c.s of the spring water were introduced into D and the air in the chamber circulated through the apparatus—bubbling through the water sample. This circulation was continued for some minutes and a reading of the α-ray activity taken with the electroscope. This procedure was repeated over a period of an hour or more, until the electroscope gave a constant reading indicating that the system had reached equilibrium. The rate of discharge of the electroscope was determined as follows: The gold leaf was observed with a telescope having a micrometer eye-piece with a scale 100 divisions in length. A suitable positive voltage (180 volts) was placed on the gold leaf which is connected to the rod of the ionization chamber, the case of the electroscope being connected to the chamber and the negative terminal of the H.T. battery. The telescope was then adjusted so that one edge of the gold leaf was just beyond one end of the scale. The battery connection to the rod was broken and the time for the gold leaf to traverse the scale determined with a stop-watch.

The gas from the spring was measured in the same way, 100 c.c. being introduced into D by displacement of water, D being inverted and the stopper with each outlet tube closed by a piece of rubber tubing and a clip inserted under water.

Standardization of Electroscope

A standard solution containing $4{\cdot}00 \times 10^{-9}$ grms. radium was prepared and introduced in a flask similar to D. The side tubes were sealed and the flask left for at least seven days to ensure that the radio-active disintegration had reached equilibrium. The flask was inserted in place of D and the α-ray activity measured as before.

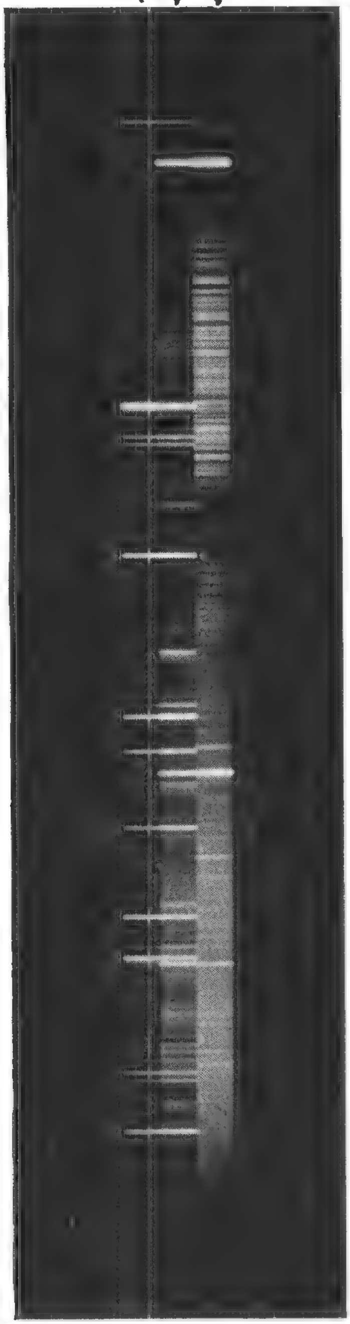
Corrections

Although the ionization chamber was large compared with the rest of the apparatus it does not contain all the gas, and the volumes of the various components must be measured in order to find what fraction the ionization chamber represents. The volume of water is equivalent to an amount of air equal to its volume x the solubility of the radio-active gas at the temperature at which the readings were taken. The gas was shown to be radon (see below), and its solubility was obtained from tables.

Since the ionization chamber represented 93% of the total volume and the volume of the rest of the apparatus varied only slightly, this correction reduces to a constant multiplier (variation $< 1\%$), and may be neglected in the calculations for relative activities.

The electroscope readings have to be corrected for natural leak, *i.e.*, the rate of discharge of the electroscope in the absence of radio-active material. Since this was at least several hours and the normal reading at most a few minutes, this correction is quite small and can be measured accurately.

The electroscope was tested for linearity, *i.e.*, as to whether the time of discharge was proportional to the radio-activity as follows. Readings were taken on a 10 mgm. and 1 mgm. standard radium tube, placed in exactly the same position some two feet from the chamber. After correcting for natural leak, these indicated a departure from linearity



The photograph shows the spectrum of the purified gas from the spring (central), with comparison spectra of helium plus mercury (top) and hydrogen (below). The most prominent lines in the Paralana gas spectrum are those of helium (notably 6563 A.U. and 5875 A.U.). The hydrogen lines (notably the strong red line 6563 A.U.) are also present. The mercury lines (i.e., 5461 A.U. and 5769-90 A.U.) are due to the mercury present in the collecting tube. There is also a faint band system, probably due to residual nitrogen. There is no trace of the neon spectrum.

of $< 4\%$. These readings covered a range at least four times that of the measurements of radio-activity, so that an error of $< 1\%$ could be expected from the lack of linearity. All readings of the rate of discharge could be obtained to within 1%.

Standardizations with two separate standard solutions agreed to about 7%, and constitute the main source of error. (Maximum error, $< 10\%$.)

Results

Time of discharge of electroscope for 100 c.c.'s of spring water:

86
84
85
85 — Mean, 85 secs.

Time of discharge of electroscope for 100 c.c.'s of gas:

11·3
11·2
11·5
11·4
11·5 — Mean, 11·4 secs.

Calibration

Time of discharge of electroscope for $4\cdot00 \times 10^{-9}$ (M.M.) gms. Ra.

I 3 mins. 46 secs. Natural leak, 30 divs./hour.
3 „ 47 „
3 „ 47 „

Average (after correction for natural leak), 3 mins. 51 secs.

II 3 mins. 30 secs. Natural leak, 25 divs./hour.
3 „ 32 „

Average (after correction for natural leak), 3 mins. 35 secs.

Mean time of discharge for $4\cdot00 \times 10^{-9}$ (M.M.) gms. Ra = 3 mins. 43 secs.
= 223 sec.

i.e., Radio-activity of the water is equivalent to—

$$\frac{4\cdot00 \times 223 \times 10^{-8}}{85} = 10\cdot5 \times 10^{-8} \text{ [gms. Ra]/litre.}$$

= 1050 Emans/litre.

Radio-activity of the gas is equivalent to—

$$\frac{4\cdot00 \times 223 \times 10^{-8}}{11\cdot4} = 78 \times 10^{-8} \text{ gms. Ra/litre.}$$

= 7,800 Emans/litre.

Thus a solubility of about 13% of the gas in the spring water would account for all of the radio-activity of the water. ·13 is the solubility of radon in water at 60° C.

DESCRIPTION OF PLATE XXI

The photograph shows the spectrum of the purified gas from the spring (central), with comparison spectra of helium plus mercury (top) and hydrogen (below). The most prominent lines in the Paralana gas spectrum are those of helium (notably 6563 A.U. and 5875 A.U.). The hydrogen lines (notably the strong red line 6563 A.U.) are also present. The mercury lines (*i.e.*, 5461 A.U. and 5769-90 A.U.) are due to the mercury present in the collecting tube. There is also a faint band system, probably due to residual nitrogen. There is no trace of the neon spectrum.

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All the samples examined fall within a characteristic grouping with respect to the mechanical composition of the mineral fraction.

While the recent deposits may contain up to 5 per cent. of soluble salts, the soils, despite their possible proximity to continuous solfataric or fumarole activity are particularly free from salt owing to the intense leaching effects prevailing under the heavy rainfall conditions.

The deposits and soils vary from slightly acid to neutral in reaction, and the latter are notable for their natural fertility.

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INTRODUCTION

New Britain, the largest of the islands of the Mandated Territory of New Guinea, is a long crescent-shaped island about 300 miles long and averaging about 60 miles wide lying about 4° to 6° south of, and roughly parallel to, the equator. With the exceptions of the Gazelle and Willaumez Peninsulas the Island is little known and remains practically unexplored, since, apart from the low-lying coastal regions, it is mostly mountainous and heavily forested. Alienated land seldom extends for more than 10 miles inland from the coast, and the greater part of the settlements occur on the low coastal strip extending between the aforementioned peninsulas.

A considerable proportion of the cultivable soils of the island of New Britain is of volcanic origin, and a number of these soils have been received from time to time for examination in this laboratory from the Department of Agriculture of New Guinea.

The recent eruptions in the neighbourhood of Rabaul towards the end of May, 1937, permitted of fresh volcanic material being collected by the Department for comparison with the soils derived from similar materials.

The soils received have been from Talasea on the Willaumez Peninsula, and from Rabaul and Kokopo on the Gazelle Peninsula. The volcanic deposits were all from Rabaul from the two craters of Vulcan Island and Matupi Island in Blanche Bay, on which the harbour of Rabaul is situated.

The rainfall at Talasea is 171 inches, of which 78% falls in the summer six months, while at Rabaul it is 88 inches and at Kokopo it is 86 inches, with summer proportions of 71% and 63%, respectively. At no time of the year are drought conditions likely to prevail, and leaching of the soil may be expected to be active during at least six months of the year.

The staple industry of the island is the cultivation of coconuts and the manufacture of such coconut products as copra, desiccated coconuts and coir fibre. Apart from the establishment of a small coffee industry and the successful growing of kapoc, little has been done in the cultivation of other crops. The Department of Agriculture is, however, investigating the possibilities of growing cocoa, tobacco, cinchona, peanuts and other tropical crops.

Reference may be made to the report of Stanley (1922) for an account of the geology and vulcanology of the island.

DESCRIPTION OF THE RECENT DEPOSITS

Seven samples of the recent deposits were collected from in and around Rabaul shortly after the recent eruption. They represented two samples of dust, one of which had been protected from rain, from Vulcan Island; four samples of mud and ash, two of which were hardened or compacted, while a third had been considerably washed and sorted by the action of torrential rains, from Matupi crater; and finally a composite sample of the total depth of deposit at Rabaul.

The deposits are fairly uniform in colour; those from Vulcan Island being of a grey-white shade, while those from Matupi are somewhat darker and vary from slate-grey to grey-black.

They are extremely light and floury, being composed mainly of particles of the dimensions of fine sand and silt. From their mechanical analysis they appear to vary in texture from sandy loams to loams bordering on clay loams. The dust deposits from Vulcan Island and the washed and sorted material fall within the former class, while the hardened mud and compacted ash from Matupi belong to the latter class; a mud layer from Matupi is intermediate in texture. From their general physical reactions and a comparison with similar deposits from New Zealand, however, they may more correctly be described as silty loams and silty clays.

Only in the sorted sample is there any appreciable concentration of pumiceous gravel and coarse sand; all the samples are, however, highly abrasive.

Analytical data for the deposits are given in Table I.

TABLE I

Analyses of Volcanic Deposits and Soils from Rabaul and Kokopo

Deposit or Soil	Sample No.	Depth of Sample in Inches	Stone in Sample	Nitrogen	Organic Carbon	Carbon to Nitrogen Ratio	P_2O_5	K_2O	Silt	Clay	Reaction
				An Air Dry Sample							
			%	%	%	(N = 1)	%	%	%	%	pH
Volcanic dust	5202	2	0	—	0.06	—	0.11	0.17	28.1	4.7	7.3
Volcanic dust	5204	2	0	—	—	—	0.11	0.10	29.0	4.6	7.7
Volcanic dust and mud	5205	6	0	—	—	—	0.11	0.26	30.7	8.5	5.1
Volcanic mud	5203	4	0	—	0.06	—	0.11	0.40	29.5	9.6	5.0
Volcanic mud	5206	—	0	—	0.06	—	0.13	0.48	30.8	21.0	7.1
Volcanic ash	5207	—	0	—	—	—	0.13	0.50	23.5	16.5	5.8
Volcanic mud & ash (1)	5208	—	8	—	—	—	0.11	0.06	26.1	4.8	7.9
Soils from Rabaul	4796	0–9	0	0.66	10.38	15.8	0.31	0.17	24.5	14.0	5.8
	4797	9–21	0	0.15	1.58	10.5	0.10	0.19	23.9	9.9	5.8
	4798	21–33	0	0.02	0.23	10.5	—	—	34.0	9.1	6.3
	4799	48	0	0.01	0.12	10.5	0.06	0.32	42.4	6.7	6.6
	4800	0–10	0	0.59	7.31	12.4	0.27	0.18	27.5	16.0	6.4
	4801	10–20	0	0.09	0.89	10.3	0.10	0.27	33.9	11.8	5.9
	4802	20–32	0	0.01	0.09	10.0	—	—	35.7	8.2	6.6
	4803	48	20.0	0.01	0.11	10.0	0.06	0.26	23.3	3.7	6.9
Soils from Kokopo	5382	0–12	—	0.42	4.37	10.5	0.21	0.26	30.1	28.9	6.9
	5383	12–24	—	0.20	2.11	10.5	0.10	0.27	33.0	21.2	6.9
	5384	24–42	—	0.08	0.91	10.8	0.03	0.14	26.4	22.3	6.9
	5385	0–12	—	0.36	3.81	10.6	0.21	0.35	29.3	22.7	7.1
	5386	12–24	—	0.08	0.78	10.2	0.15	0.34	25.0	11.0	7.0
	5387	24–36	3.4	0.03	0.27	10.2	—	—	16.2	4.8	7.4
	5388	36–42	2.4	0.01	0.08	10.6	0.13	0.28	14.3	5.8	7.4

(1) Washed and sorted by thunderstorms.

DESCRIPTION OF THE SOILS

Thirty-nine soil samples, representing two profiles from the vicinity of Rabaul, two profiles from the subdistrict of Kokopo, and five profiles from the district of Talasea, have been investigated, and the analytical data are given in Tables I and II. Apart from the Rabaul profiles, one of which is from under virgin forest and the other from under a Kunai grass cover, the soils have been taken from plantations either under or cleared for cultivation.

The soils have developed on geologically recent deposits consisting of volcanic showers of ash and mud and andesitic, rhyolitic or pumiceous sand, and despite the high leaching effect of the rainfall are still extremely immature in their development. From an examination of the stone within the profiles and from a consideration of the mechanical analyses of the soils, it is apparent that a number of showers have been deposited one on top of the other in each of the areas. At least three distinct layers, in which the material varies from distinctly pumiceous to andesitic or rhyolitic in character, are to be observed in the profiles from Talasea. In the profiles from Rabaul and Kokopo, the layering is by no means as definite, but, nevertheless, apparent. The pumiceous type of parent material dominates the soils from Rabaul and Kokopo while the vitreous andesitic

TABLE II

Analyses of Volcanic Soils from Talasea

Locality	Sample No.	Depth of Sample in Inches	Stone in Sample %	Nitrogen %	Carbon %	Carbon to Nitrogen Ratio (N = 1)	On Air Dry Soil: P_2O_5 %	K_2O %	Silt %	Clay %	Reaction pH
Site 1	5065	0–12	0.0	0.51	5.20	10.1	0.33	0.18	18.9	24.5	6.6
	5066	12–24	5.3	0.04	0.41	9.8	0.09	0.31	15.9	4.1	6.8
	5067	24–36	30.1	0.00	0.04	10.0	—	—	6.2	1.7	7.1
	5068	36–48	24.2	—	—	—	—	—	—	—	7.3
	5069	48–72	19.3	—	—	—	—	—	—	—	7.2
Site 2	5074	0–12	0.0	0.32	3.34	10.3	0.26	0.13	17.5	13.2	6.4
	5075	12–24	5.2	0.05	0.50	10.2	0.14	0.18	18.5	20.7	6.8
	5076	24–48	2.6	0.00	0.06	10.0	—	—	—	—	6.8
	5077	48–72	10.2	—	—	—	—	—	—	—	6.9
Site 3	5078	0–6	0.0	0.47	4.94	10.5	0.31	0.15	18.2	25.1	6.2
	5079	6–12	1.4	0.15	1.53	10.0	0.16	0.15	19.3	36.0	6.6
	5080	12–24	5.8	0.06	0.60	10.0	0.10	0.23	18.6	33.1	6.7
	5081	24–36	29.3	0.01	0.08	10.0	—	-	6.5	2.1	6.2
	5082	36–48	18.1	—	—	—	0.07	0.16	3.5	1.1	6.7
	5083	48–72	18.2	0.01	0.06	10.0	—	—	3.8	2.4	6.8
Site 4	5088	0–12	2.3	0.28	2.76	9.9	0.17	0.11	19.1	19.5	6.6
	5089	12–24	8.3	0.12	1.26	10.6	0.11	0.13	16.0	8.8	6.5
	5090	24–36	15.2	0.01	0.10	10.0	—	—	2.1	1.4	6.5
	5091	36–48	28.3	—	—	—	—	—	—	—	7.0
	5092	48–60	12.5	0.00	0.03	10.0	—	—	—	—	6.9
Site 5	5097	0–6	0.0	0.53	5.73	10.8	0.18	0.14	18.4	17.1	6.9
	5098	6–24	1.9	0.06	0.64	10.7	—	—	19.8	18.2	6.7
	5099	24–48	8.2	0.02	0.24	10.8	0.08	0.13	9.0	3.8	6.5
	5100	48–72	0.0	0.01	0.12	10.8	—	—	14.8	7.0	6.9

or rhyolitic types are more pronounced, particularly in the lower layers, from Talasea; gravel and stone are a very characteristic feature of the latter profiles.

The soils from the two centres, while showing little variation in their chemical characteristics, show some marked differences in their physical and mechanical composition, and the general profile from each district is best described separately.

The profiles from Rabaul and Kokopo (see fig. I) consist of from 9 to 12 inches of a dark grey-brown (black under virgin conditions) light clay to clay

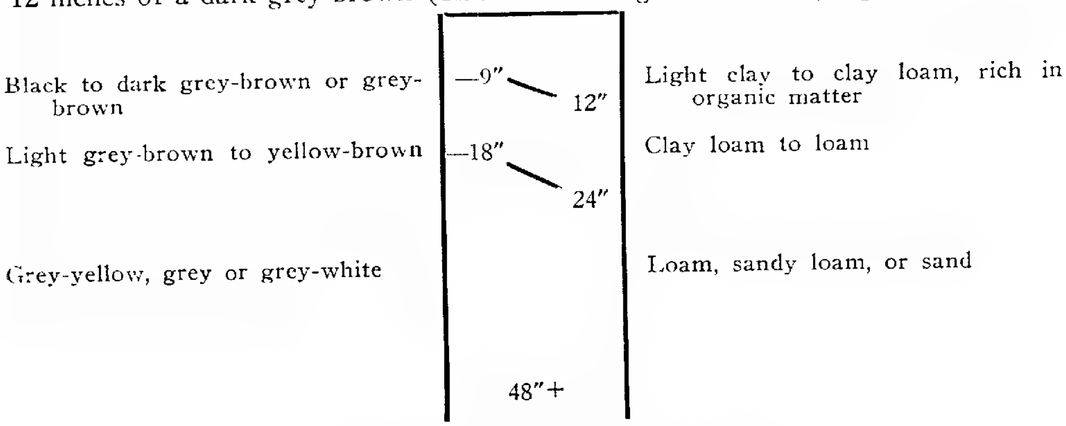

Fig. 1

Soil Profile from Rabaul or Kokopo

loam surface layer, rich in organic matter, overlying a light grey-brown to yellow-brown clay loam to loam to a depth of 18 to 24 inches. Below 24 inches the colour varies somewhat from grey-yellow to almost white, the lightening in colour becoming more pronounced with depth, and the texture is more definitely sandy. There is only a small concentration of pumiceous stone in the profile, although it may become somewhat pronounced in the lower and more sandy layers.

Layering is a much more definite characteristic of the soils examined from Talasea; there is a very definite break from the loamy textured layers to extremely coarse sands at about 24 inches. The soil profile, which is illustrated in figure 2, consists of a 12-inch surface layer of very dark brown to grey-yellow-brown clay

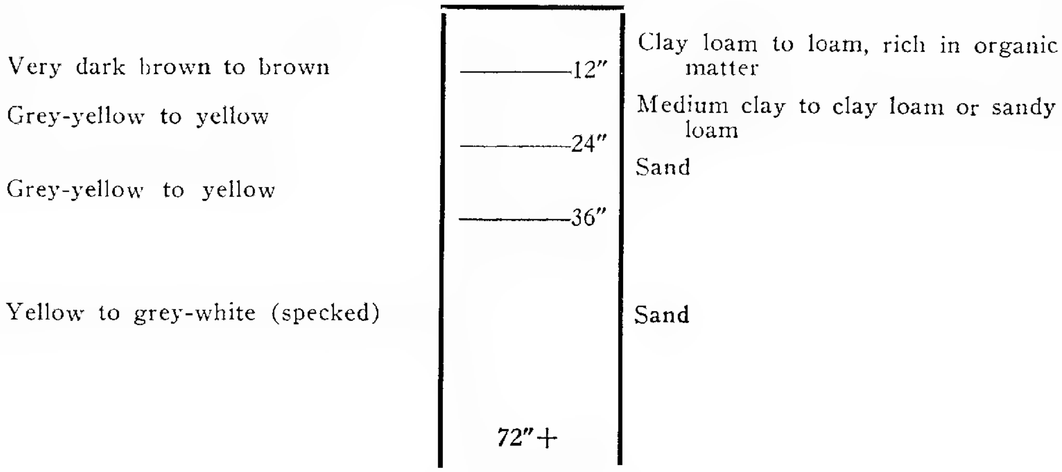

Fig. 2
Soil Profile from Talasea

loam to loam, rich in organic matter, overlying a light brown to grey-yellow, medium clay to sandy loam. Below 24 inches the soil consists of extremely sandy deposits of volcanic ejectamenta, somewhat variable in colour although a yellow shade, increasing in intensity with depth, predominates.

While the surface layer of the soils to a depth of about 12 inches is practically free from stone, about 6%, principally pumiceous, occurs in the second foot. Pumiceous and other stones reach a maximum concentration (up to 30%) in the third or fourth foot, where lumps of pumice, up to several inches in diameter, may be found. Below 36 inches the lumps of pumice decrease in size and amount, and their place is taken by less scoreaceous and smaller fragments of more vitreous material. In the lower layers these latter fragments together with glassy material and large grains of heavy minerals are present, to the virtual exclusion of pumice within the gravel fraction.

Like the fresh deposits all these volcanic soils, apart from the most sandy samples, have a distinctly silty feel and may similarly be described as silty clays and silty loams.

MECHANICAL COMPOSITION

The samples of both the volcanic deposits and the soils have been mechanically analysed, and while the individual figures for clay and silt are given in Tables I and II, the complete results are summarised in Tables III and IV.

TABLE III

Mechanical Analyses of Deposits resulting from the Volcanic Eruption at Rabaul in May, 1937. (The figures have been recalculated to the basis, Sand + Silt + Clay = 100%)

Crater Source	Sample No.	Coarse Sand	Fine Sand 0.2 mm. to 0.04 mm.	Fine Sand Very Fine Sand, 0.04 mm. to 0.02 mm.	Silt	Clay
		%	%	%	%	%
Vulcan Island ...	5202	8	25	34	28	5
Vulcan Island ...	5204	13	21	32	29	5
Composite	5205	7	21	31	32	9
Matupi	5203	5	22	30	32	11
Matupi	5207	15	19	22	26	18
Matupi	5206	3	14	27	33	23
Matupi	5208	33	15	21	26	5

TABLE IV

Average Mechanical Analyses of Soils formed on Volcanic Deposits. (The figures have been recalculated to the basis, Sand + Silt + Clay = 100%)

Locality	Depth in Inches	Coarse Sand	Fine Sand 0.2 mm. to 0.04 mm.	Fine Sand Very Fine Sand 0.04 mm. to 0.02 mm.	Silt	Clay
Rabaul and	0–12	5	9	21	38	27
Kokopo	12–24	14	14	24	33	15
	24–36	18	16	25	30	11
	> 36	23	19	25	28	5
Talasea	0–12	14	17	18	24	27
	12 24	24	17	16	22	21
	24–36	65	20	7	6	2
	> 36	78	13	3	4	2

The major characteristic is seen to be a high very fine sand plus silt content, which amounts to from 50% to 60% in the deposits and soils from Rabaul and Kokopo The change in the sandiness of the soils with depth reflects the nature of the deposition of the parent materials; the coarser deposits having settled first and being covered in turn by medium and finer-grained materials.

In figure 3 the mechanical analyses of the samples have been plotted on a distribution triangle. In addition the area of the triangle within which the composition of soils developed on similar parent materials from Mount Gambier in South Australia[2] and from New Zealand (Grange et. al. 1932) may be found, has been shown for comparison. All the deposits and soils fall into a characteristic grouping with respect to the mechanical composition of the mineral

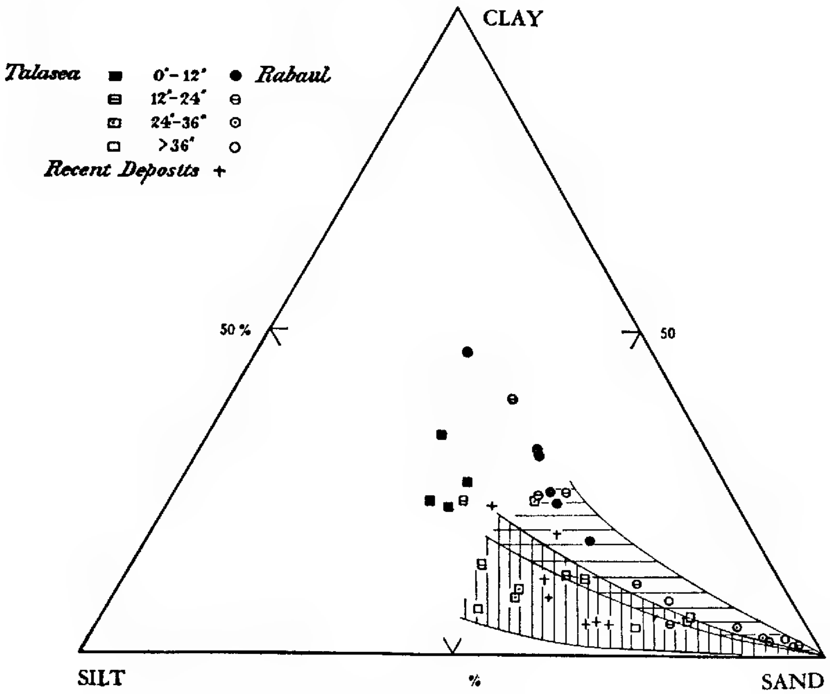

Fig. 3

Triangular diagram illustrating the mechanical analyses of the volcanic deposits and soils from the Island of New Britain. Shaded areas represent those within which soils from South Australia and New Zealand formed on similar parent materials occur. Vertical shading—pumiceous and rhyolitic types. Horizontal shading—andesitic and basaltic types.

fraction, with those of an essentially pumiceous or rhyolitic origin showing a definitely more pronounced silt content in relation to the clay, than those of a more basic, andesitic or basaltic, origin. The pumiceous nature of the deposits from the Vulcan Island crater and soils from Rabaul and Kokopo and the more basic nature of the soils from Talasea are indicated by their position in the triangle. There is a very much more marked scatter in the case of the former than the latter soils which lie practically on a continuous curve.

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[2] From the Waite Institute records.

A more detailed analysis, by sieving of the sand fractions, was carried out for a number of the samples and the summation curves and probable frequency distribution curves derived therefrom, down to the lower limit of the silt fraction, are shown in figure 4. A maximum concentration of particles with a grain size around the fine sand-silt limit is characteristic of all the samples, and most pronounced in the deposits and soils from Rabaul. Further maxima, within the fine

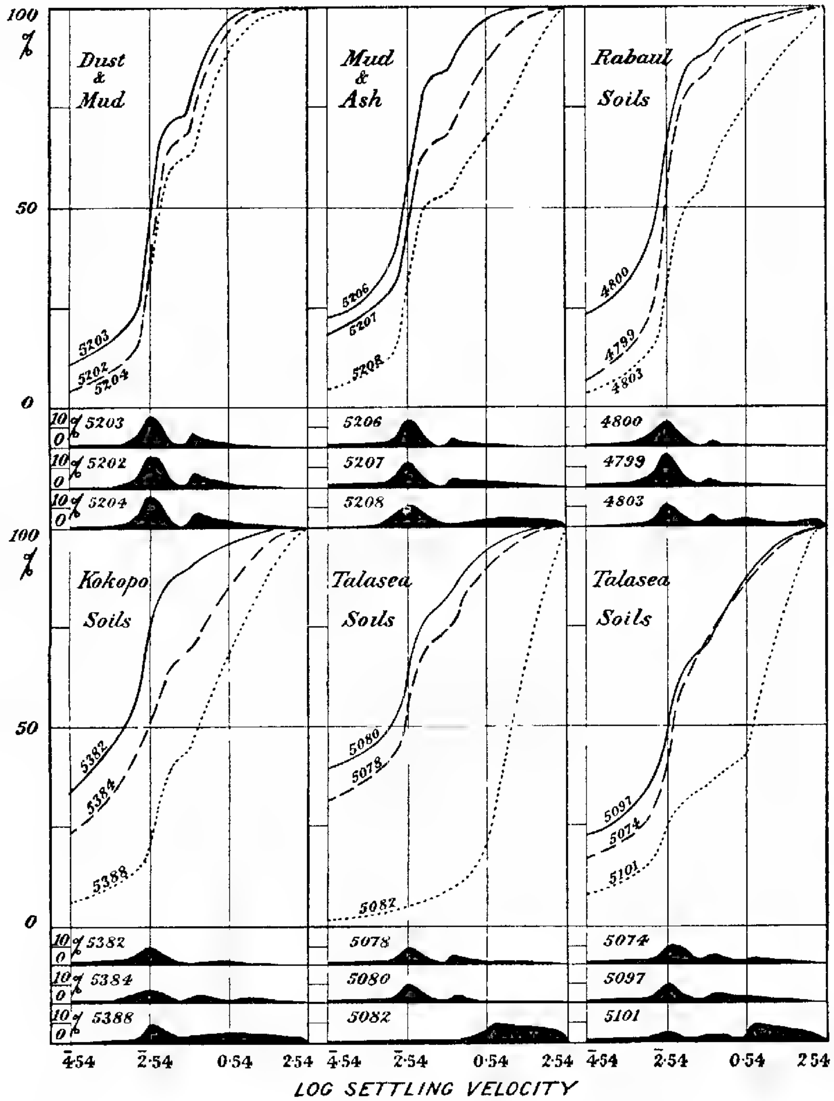

Fig. 4

Summation curves of the mechanical analyses and the probable frequency distribution curves derived therefrom, to the upper limit of the clay fraction, of typical samples of the volcanic deposits and soils from New Britain; ten intervals are allowed to each of the three fractions silt, fine sand and coarse sand in the latter curves. The high frequency of particles around the silt-fine sand limit is to be noted.

sand fraction, and just above the lower limit of the coarse sand in the sandy sub-soil layers, are also prominent.

In Table V the mean values for certain physical properties as determined by the method of Keen and Raczkowski (1921) are given. The low values for the weight per unit volume (apparent specific gravity) of the surface soils, and dust samples from Vulcan Island, emphasise their powdery nature, while the high values for the water-holding capacity of the pumiceous samples are indicative of their extreme porosity.

TABLE V

Some Physical Properties of the recent Volcanic Deposits and Volcanic Soils

Deposit or Soil	Depth in Inches	Clay %	Organic Matter %	Weight of Unit Volume	Total Water Holding Capacity %	Volume Expansion of 100 ccs. %
Vulcan Island Deposits ..	—	5	0·1	1·11	51·3	1·6
Matupi Deposit	—	16	0·1	1·22	44·7	0·0
Matupi Deposit	—	5	0·1	1·23	47·1	8·8
Soils from Rabaul and Kokopo	0–12	20	11·1	0·82	115·4	22·2
	12–24	13	2·3	0·91	93·0	17·4
	> 24	9	0·5	1·07	65·0	15·0
Soils from Talasea	0–12	21	7·0	0·94	97·7	22·2
	> 24	2	0·1	1·07	43·2	12·2
	*	7	0·2	0·76	107·8	14·2

* Sample 5100 extremely soft hydrated pumiceous material.

The very low to negligible volume expansion of the recent deposits shows that the fraction determined as clay represents in reality the final stage in mechanical disintegration of the original material rather than a final stage in chemical weathering, and should strictly speaking be included with the silt. Following the operation of soil-forming processes, however, true mineralogical clay species, with the normal property of swelling, are formed.

CHEMICAL CHARACTERISTICS

The deposits and soils have been examined by the usual standard methods of chemical analysis, and the values, for the various constituents determined, are given in detail in Tables I and II and summarised in further tables of the text.

SOLUBLE SALTS

The recent deposits were examined for soluble salts by extracting 200 gms. with one litre of distilled water. Owing, however, to the approximate saturation of the aqueous solutions obtained from the deposits containing the larger amounts of calcium sulphate, it was necessary to determine the total calcium sulphate by extraction with standard hydrochloric acid. The results are given in Table VI.

TABLE VI

Analyses of Soluble Salts in the Volcanic Deposits from the Eruption at Rabaul in May, 1937

Source of Deposit	Vulcan Island Crater		Both Craters	Matupi Crater			
Nature of Deposit	Dust Protected from Rain	Dust Underlying 5203	Composite Sample of Dust and Mud	Mud Overlying 5204	Hardened Mud	Compacted Ash	Washed and Sorted by Thunder Storms
Sample Number	5202	5204	5205	5203	5206	5207	5208
Ions ..	%	%	%	%	%	%	%
Calcium	0·22	0·15	0·97	1·18	1·01	1·21	0·009
Magnesium	0·03	0·03	0·07	0·09	0·04	0·15	0·001
Sodium	0·22	0·17	0·25	0·32	0·08	0·28	0·018
Potassium	0·02	0·02	0·03	0·04	0·03	0·05	0·006
Manganese	0·001	0·002	0·005	0·006	0·004	0·013	0·000
Sulphate	0·42	0·35	2·14	2·70	2·22	3·12	0·020
Chloride	0·46	0·34	0·49	0·69	0·13	0·49	0·035
Carbonate	0·001	0·000	0·000	0·000	0·001	0·000	0·001
Total	1·37	1·06	3·96	5·03	3·52	5·31	0·090
Salts expressed as:							
Gypsum—							
$CaSO_4 2H_2O$	0·75	0·63	3·83	4·83	3·97	5·59	0·036
(Ca, Mg, Mn) $Cl_2 6H_2O$ ...	0·23	0·16	0·50	0·50	0·42	0·67	0·007
Sodium Chloride—							
(Na,K) Cl	0·60	0·47	0·70	0·89	0·26	0·81	0·058
Reaction ... pH	7·3	7·7	5·1	5·0	7·1	5·8	7·9

The salt content is seen to vary from 4% to 5% in the more acid deposits, to about 1 % in the slightly alkaline Matupi mud layer. The rapidity with which the salts may be leached from the deposits is indicated by the very low content, less than 0·1%, in the sample which has been subjected to the action of water.

Calcium sulphate (gypsum) and sodium chloride constitute the bulk of the soluble salts, although potassium and magnesium salts are also present. While the calcium sulphate is a natural result of the fumarole action during volcanic activity, the high content of sodium chloride is undoubtedly due to contamination with sea-water. At the bottom of Table VII the ionic concentrations are expressed in terms of the probable salt species present.

Despite the close proximity of solfataric and fumarole action the soils are particularly free from salts, due to the intense leaching under the prevalent heavy rainfall conditions.

Reaction

The reaction of the samples was determined by means of the glass electrode, using a ratio of sample to water of 1 to 5, and the results are summarised in Table VII.

Table VII

Distribution Table for the Reaction of the Volcanic Deposits and Soils from the Districts of Rabaul and Talasea

	Depth of Soil in Inches	Reaction Value pH 5.0 to 5.5	5.5 to 6.0	6.0 to 6.5	6.5 to 7.0	7.0 to 7.5	7.5 to 8.0	Variation Mean pH	Max. pH	Min. pH
Deposits	—	2	1	—	—	2	2	6·6	7·9	5·0
Soils	0–12	—	1	3	4	1	—	6·6	7·1	5·8
	12–24	—	1	1	6	1	—	6·6	7·0	5·8
	24–36	—	—	2	5	2	—	6·7	7·4	6·2
	36–48	—	—	1	5	3	—	6·9	7·4	6·5
	48–72	—	—	—	4	1	—	7·0	7·2	6·8

Despite the presence of sulphur dioxide and hydrogen sulphide in the gaseous emanations during the volcanic activity the deposits contain no free acid, but it may be observed that the deposits containing the larger proportions of calcium sulphate show a slightly acid reaction. With a removal of the salts there is a change to slight alkalinity.

The soils themselves all show slightly acid to neutral reactions. There is little more than 1 pH unit variation from profile to profile, and within the individual profiles there is generally a change from slight acidity in the surface layers to neutrality or faint alkalinity at the lower depths.

Nitrogen, Organic Carbon and Organic Matter

The mean values and range for the nitrogen and carbon contents and the carbon to nitrogen ratio for the various soil layers are given in Table VIII.

Table VIII

Mean Value and Range for Nitrogen and Organic Carbon Contents and Carbon to Nitrogen Ratio in the Volcanic Soils from Rabaul and Talasea

Depth of Soil in Inches	Number of Samples	Nitrogen (N) Mean %	Nitrogen (N) Max. %	Nitrogen (N) Min. %	Carbon (C) Mean %	Carbon (C) Max. %	Carbon (C) Min. %	Carbon : Nitrogen (N = 1) Mean	Carbon : Nitrogen (N = 1) Max.	Carbon : Nitrogen (N = 1) Min.
0–12	9	0·443	0·660	0·277	5·13	10·38	2·76	11·2	15·8	9·9
12–24	9	0·094	0·200	0·042	0·97	2·11	0·41	10·3	10·7	9·8
24–36	9	0·021	0·078	0·004	0·22	0·91	0·04	10·3	10·8	10·0
$>$ 36	6	0·008	0·012	0·003	0·09	0·12	0·03	10·3	10·8	10·0

The soils are particularly well supplied with organic matter down to a depth of from 12 to 24 inches, but below the surface the content falls off markedly and progressively in descending the profile.

A remarkable uniformity in the value of the carbon to nitrogen ratio throughout the whole range of soils is to be observed. Only in the two surface samples from Rabaul, where ratios of 15·8 and 12·4 are found, does the ratio vary more than about 0·5 unit from a mean value of 10·3.

A small proportion of organic matter, about 0·1%, derived no doubt from contact with the atmosphere, is present in the volcanic deposits.

Phosphoric Acid and Potash

Table IX

Mean Value and Range of Acid Soluble Phosphoric Acid and Potash in the Volcanic Deposits and Soils from Rabaul and Talasea

	Depth of Soil in Inches	Number of Samples	Phosphoric Acid (P_2O_5)			Potash (K_2O)		
			Mean %	Max. %	Min. %	Mean %	Max. %	Min. %
Deposits	—	7	0·12	0·13	0·11	0·28	0·50	0·06
Soils	0–12	9	0·23	0·33	0·17	0·19	0·35	0·11
	12–24	8	0·11	0·15	0·09	0·24	0·34	0·13
	$>$ 24	6	0·07	0·13	0·03	0·22	0·32	0·13

The contents of both phosphoric acid and potash, as determined in the standard hydrochloric acid extract (see Table IX), are very satisfactory from the point of view of plant nutrition.

The deposits and subsoil samples show a fairly uniform content of phosphoric acid, about 0·1%. In the surface soil samples the content is much higher and the excess amount, over and above that extracted from the recent deposits, appears to bear a close relationship to the organic matter content.

Some variation is seen to occur in the content of potash, not only of the soils but also of the deposits, which in general show somewhat higher concentrations than the former. Within the soil profiles there is no general variation with depth, a similar range in the content of potash being experienced in each layer.

Acknowledgments

The author wishes to express his thanks to Mr. G. H. Murray, Director of Agriculture, New Guinea, for his permission to publish the results of the analyses of these deposits and soils, which were sent officially from the Department of Agriculture to the Division of Soils; and also to Mr. B. G. Challis, an officer of the Department, for detailed information regarding the recent eruption.

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Stanley, E. R. 1922 Report to the League of Nations on the Administration of the Territory of New Guinea from 1 July 1921 to 30 June 1922 Appendix B

OBITUARY NOTICES

WALTER CHAMPION HACKETT

Summary

Mr. W. C. Hackett (74), formerly of Dequetteville Terrace, Kent Town, who died at a North Adelaide private hospital on 25 May 1938 after a long illness, was one of Australia's most widely known horticulturists. Born at Norwood, Mr. Hackett was educated at St. Peter's College. Leaving school, he entered his father's business in 1880 as a seedsman and nurseryman, and followed that calling for 40 years. He was a foundation director of the firm of E. & W. Hackett.

OBITUARY NOTICES

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Greatly interested in floriculture, he was secretary of the S.A. Horticultural and Floricultural Society for 35 years. He was also a member of the executive of the Royal Agricultural and Horticultural Society of South Australia and acted as one of its judges for many years.

One of Mr. Hackett's greatest interests was the Royal Society, to which he was elected in 1916 and which he served as Honorary Auditor until his death. He was Chairman of the Field Naturalists' Section. He was a great supporter of the Fauna and Flora Protection Committee which, with the Royal Society, was responsible for the National Park and Flinders' Chase being secured for the people.

He was elected a Fellow of the British Royal Horticultural Society in 1888, and was a Life Member of the Royal Colonial Institute.

EDWARD MEYRICK, B.A., F.R.S.

Edward Meyrick, who was the world authority on the Micro-lepidoptera, passed away at his residence at Marlborough, Wiltshire, England, in his eighty-fifth year. From an early age, Meyrick took an interest in the Lepidoptera and soon made the smaller forms his particular study, his first published note appearing in 1875.

In 1877 he took up a scholastic post at Sydney, and a few years later a similar post at Christchurch, New Zealand. During these years he found an astonishing variety of micro-lepidoptera, and made thorough and intensive collections. On his return to England in 1887 he became assistant master at the public school at Marlborough, and from thence came a great succession of papers dealing with these small moths from all regions of the world.

During his active work it has been estimated that he described some 20,000 species, besides many genera and families. His outstanding work was probably the "Handbook of British Lepidoptera," in which he placed the classification on a sound basis.

He was elected an Honorary Fellow of this Society in 1898, and our Transactions contain many papers dealing with his own groups.

Not only the Society, but entomology in general and Australian entomology in particular, are poorer by the loss of this authority, for there are few younger workers of his calibre to continue the much-needed work still to be done.

CHARLES ALLEN SEYMOUR HAWKER, M.A., M.H.R.

The late Capt. C. A. S. Hawker was born on 16 May 1894 at "Bungaree," Clare, South Australia, which estate was established by his grandfather, the Hon. G. C. Hawker, M.P., who came to Australia in the "Lysander" in 1840.

Capt. Hawker was educated at Geelong Grammar School and Trinity College, Cambridge, where he took his M.A. degree.

He enlisted in 1914 in the Somerset Light Infantry and saw service in France and Belgium. Thrice wounded, he was invalided with the rank of Captain and returned to Australia, where he took up pastoral pursuits. He was Vice-President of the Returned Soldiers' Association in 1921, and a member of the Commonwealth Board of Trade in 1927. In 1929 he was elected to the Commonwealth Parliament for Wakefield, which seat he retained until his untimely death. During this time he held the position of Minister of Markets, of Repatriation, and became the first Minister of Commerce.

He was elected a Fellow of this Society in 1924, and although he did not take a very active part in the meetings of the Society, his loss will be deeply felt. The worst air tragedy of this country, on 25 October, has not only deprived us of a valued member, but the country is the poorer for the death of a great statesman and patriot who has carried on the highest traditions of a distinguished family.

JOHN SUTTON

The late Mr. John Sutton was elected a Fellow of the Society in 1922. He passed away on 22 November in his seventy-fourth year after a short illness.

Mr. Sutton took up the study of birds seriously at the age of 53, and after the death of Mr. F. R. Zietz, when Dr. A. M. Morgan became Honorary Ornithologist at the S.A. Museum, he joined him as Assistant Honorary Ornithologist. During his 15 years work in this position he put the large collections of birds on a sound and efficient basis of cataloguing, personally registering about 15,000 specimens.

On the death of Dr. Morgan he became Honorary Ornithologist.

From 1922 until he retired in March last he was Honorary Secretary of the South Australian Ornithologists' Association. In 1927 he joined the editorial committee of the "South Australian Ornithologist," and to his enthusiasm and ability the success of this publication was largely due.

Mr. Sutton was the author of many scientific publications on birds and their habits, printed in the "Emu" and the "South Australian Ornithologist."

Until recent years Mr. Sutton was a frequent attender at our meetings.

ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED).

Receipts and Payments account for the Year ended September 30, 1938.

ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED).

Receipts and Payments for the Year ended 30 September 1938

RECEIPTS.

	£ s. d.	£ s. d.
To Balance, 1 October 1937		388 11 8
,, Subscriptions		161 19 0
,, Government Grant for Printing		181 8 0
,, Professor T. Harvey Johnston—		
Part Cost Printing Paper	3 0 0	
,, Use of Room by other Societies	16 4 3	
,, Sale of Publications	6 2 10	
,, Exchange on Remittances	0 5 0	
		25 12 1
,, Interest—		
Transferred from Endowment Fund		179 6 8
		£936 17 5

PAYMENTS.

	£ s. d.	£ s. d.
By Transactions (Vol. 61 and Vol. 62, Pt. 1)—		
Printing	441 18 3	
Illustrating	149 9 4	
Publishing	22 7 6	
		613 15 1
,, Librarian		40 10 0
,, Sundries—		
Cleaning and Lighting	22 18 8	
Printing, Postages and Stationery	28 17 5	
Petties	5 14 9	
Typing	3 10 0	
Insurance	6 13 4	
Bank Fee and Cheque Books	0 15 0	
		68 9 2
,, Endowment Fund		19 19 1
,, Balance, 30 September 1938—		
Savings Bank of S.A.	167 1 11	
Bank of Australasia	27 2 2	
		194 4 1
		£936 17 5

Audited and found correct. We have verified the respective Bank Balances.

O. GLASTONBURY, F.A.I.S., A.F.I.A. } Hon.
F. M. ANGEL } Auditors

Adelaide, 7 October 1938

W. CHRISTIE, Hon. Treasurer.

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(a) ENDOWMENT FUND as at 30 September 1938

(Capital —Stocks at Cost Price £5,782 11s. 1d.)

	£ s. d.	£ s. d.		£ s. d.	£ s. d.
1937—1 October			1938—30 September		
To Balance—			By Revenue Account		179 6 8
Australian Consolidated Stock	4,982 0 0		„ Balance—		
Savings Bank of S.A.	20 11 1		Australian Consolidated Stock	5,762 0 0	
		5,002 11 1	Savings Bank of S.A.	20 11 1	
„ Estate Late Sir Joseph Verco		760 0 11			5,782 11 1
„ General Fund		19 19 1			
„ Interest—					
Inscribed Stocks	166 18 0				
Savings Bank of S.A.	12 8 8				
		179 6 8			
		£5,961 17 9			£5,961 17 9

(b) RESEARCH FUND as at 30 September 1938

	£ s. d.		£ s. d.
1937—1 October		1938—30 September	
To Balance	16 0 0	By Balance—Savings Bank of S.A.	16 0 0

Audited and found correct. We have verified the Government Stocks at the Registries of Inscribed Stocks, Adelaide, and the Bank Balances at the Savings Bank of South Australia.

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1932. *GIBSON, E. S. H., B.Sc., 297 Cross Roads, Clarence Gardens, Adelaide.
1935. GLASTONBURY, J. O. G., B.A., M.Sc., Dip.Ed., 4 Mornington Road, Unley, S.A.
1919. †GLASTONBURY, O. A., Adelaide Cement Co., Brookman Buildings, Grenfell Street, Adelaide, S.A.
1927. GODFREY, F. K., Robert Street, Payneham, S.A.
1935. †GOLDSACK, HAROLD, Coromandel Valley.
1925. †GOSSE, J. H., Gilbert House, Gilbert Place, Adelaide.
1880. *GOYDER, GEORGE, A.M., B.Sc., F.G.S., 232 East Terrace, Adelaide, S.A.
1910. *GRANT, KERR, M.Sc., Professor of Physics, University, Adelaide, S.A.

Date of Election.

1933. Gray, J. H., M.B., B.S., Orroroo, S.A.
1930. Gray James T., Orroroo, S.A.
1933. Greaves, H., Director, Botanic Gardens, Adelaide.
1904. Griffith, H. B., Dunrobin Road, Brighton, S.A.
1934. Gunter, Rev. H. A., Riverton, S.A.
1927. *Hackett, C. J., M.D., c/o Bank of Adelaide, London.
1922. *Hale, H. M., The Director, S.A. Museum, Adelaide—**Council**, 1931-34; **Vice-President**, 1934-36; 1937-8; **Treasurer**, 1938-.
1924. Hawker, Captain C. A. S., M.A., M.H.R., Dillowie, Hallett, South Australia.
1927. Holden, The Hon. E. W., B.Sc., Dequetteville Terrace, Kent Town, Adelaide.
1933. Hosking, H. C., B.A., 24 Northcote Terrace, Gilberton, Adelaide.
1930. *Hosking, J. S., B.Sc., Waite Agricultural Research Institute, Glen Osmond, S.A.
1924. *Hossfeld, Paul S., M.Sc., Office of Home and Territories, Canberra, F.C.T.
1928. Ifould, Percy, Kurralta, Burnside, S.A.
1918. *Ising, Ernest H., c/o Comptroller's Office, S.A. Railways, Adelaide—**Council**, 1934-.
1918. *Jennison, Rev. J. C., 7 Frew Street, Fullarton, Adelaide.
1910. *Johnson, E. A., M.D., M.R.C.S., 8 Victoria Avenue, Unley Park, Adelaide.
1934. Johnston, J., A.S.A.S.M., A.A.I.C., A.A.C.I., Sewage Treatment Works, Glenelg, S.A.
1921. *Johnston, Professor T. Harvey, M.A., D.Sc., University, Adelaide—**Sir Joseph Verco Medal**, 1935; **Rep.-Governor**, 1927-29; **Council**, 1926-28; **Vice-President**, 1928-31; **President**, 1931-32; **Secretary**, 1938-; **Rep. Fauna and Flora Board**, 1932-.
1929. Johnston, W. C., Manager, Government Experimental Farm, Kybybolite, S.A.
1920. *Jones, Professor F. Wood, M.B., B.S., M.R.C.S., L.R.C.P., D.Sc., F.R.S., University of Manchester—**Rep. Governor**, 1922-27; **Council**, 1921-25; **President**, 1926-27; **Vice-President**, 1925-26; **Rep. Fauna and Flora Board**, 1922-26.
1933. *Kleeman, A. W., M.Sc., 46 Byron Road, Black Forest, S.A.
1922. Lendon, Guy A., M.D., B.S., M.R.C.P., North Terrace, Adelaide, S.A.
1930. *Louwyck, Rev. N. H., 85 First Avenue, St. Peters, Adelaide.
1938. Love, Rev. J. R. B., M.C., D.C.M., M.A., Kunmunya Mission, *via* Broome, Western Australia.
1931. *Ludbrook, Mrs. N. H., M.A., Elimatta St., Reid, F.C.T.
1938. Madern, C. B., B.D.S., D.D.Sc., Shell House, North Terrace, Adelaide.
1922. *Madigan, C. T., M.A., B.E., D.Sc., F.G.S., University of Adelaide—**Council**, 1930-33; **Vice-President**, 1933-35, 1936-37; **President**, 1935-36.
1923. Marshall, J. C., Mageppa Station, Comaum, S.A.
1933. Magarey, Miss K. de B., B.A., B.Sc., 301 Unley Road, Adelaide.
1932. Mann, E. A., C/o Bank of Adelaide, Adelaide.
1929. Martin, F. C., M.A., Technical High School, Thebarton, S.A.
1905. *Mawson, Sir Douglas, O.B.E., D.Sc., B.E., F.R.S., Professor of Geology, University of Adelaide—**Sir Joseph Verco Medal**, 1931; **Rep. Governor**, 1933-; **President**, 1924-25; **Vice-President**, 1923 24, 1925-26.
1938. *Mawson, Miss P. M., M.Sc., University, Adelaide.
1920. Mayo, Herbert, LL.B., K.C., 16 Pirie Street, Adelaide.
1934. McCloughry, C. L., B.E., A.M.I.E., (Aust.), City Engineer's Office, Town Hall, Adelaide, S.A.
1929. McLaughlin, E., M.B., B.S., M.R.C.P., 2 Wakefield Street, Kent Town, Adelaide.
1907. Melrose, Robert T., Mount Pleasant, S.A.
1925. †Mitchell, Professor Sir W., K.C.M.G., M.A., D.Sc., Fitzroy Terrace, Prospect, Adelaide
1933. Mitchell, Professor M. L., M.Sc., University of Adelaide.
1938. Moorhouse, F. W., M.Sc., Chief Inspector of Fisheries, Flinders Street, Adelaide.
1924. Morison, A. J., Town Clerk, Town Hall, Adelaide, S.A.
1930. Morris, L. G., Beehive Buildings, King William Street, Adelaide.
1936. *Mountford, C. P., 25 First Avenue, St. Peters, Adelaide.
1925. †Murray, Hon. Sir George, K.C.M.G., B.A., LL.M., Magill, S.A.
1930. Ockenden, G. P., Public School, Norton's Summit, S.A.
1913. *Osborn, T. G. B., D.Sc., Professor of Botany, University, Oxford, England—**Council**, 1915-20, 1922-24; **President**, 1925-26; **Vice-President**, 1924-25, 1926-27.
1937. Parkin, Leslie W., University, Adelaide.
1929. Paull, Alex. G., M.A., B.Sc., Box 145, Port Lincoln, S.A.
1924. Perkins, Professor A. J., Marlborough Street, Brighton.

Date of Election.

1928. PHIPPS, IVAN F., Ph.D., B.Ag.Sc., Waite Agricultural Research Institute, Glen Osmond, S.A.

1926. *PIPER, C. S., M.Sc., Waite Agricultural Research Institute, Glen Osmond, S.A.

1936. PLATT, PROFESSOR A. E., M.D., B.S., D.T.M., D.T.H. (Syd.), Dip.Bact. (London), F.R.A.C.P., Adelaide Hospital, Adelaide, S.A.

1925. *PRESCOTT, PROFESSOR J. A., D.Sc., A.I.C., Waite Agricultural Research Institute, Glen Osmond, S.A.—**Sir Joseph Verco Medal**, 1938; **Council**, 1927-30, 1935-; **Vice-President**, 1930-32; **President**, 1932-33.

1926. PRICE, A. GRENFELL, C.M.G., M.A., Litt.D., F.R.G.S., St. Mark's College, North Adelaide.

1937. *RAIT, W. L., M.Sc., St. Peter's College, Adelaide, S.A.

1925. RICHARDSON, A. E. V., M.A., D.Sc., Council for Scientific and Industrial Research, 314 Albert Street, East Melbourne.

1905. *ROGERS, R. S., M.A., M.D., D.Sc., F.L.S., 52 Hutt Street, Adelaide—**Council**, 1907-14, 1919-21; **President**, 1921-22; **Vice-President**, 1914-19, 1922-24.

1933. SCHNEIDER, M., M.B., B.S,. 175 North Terrace, Adelaide.

1924. *SEGNIT, R. W., M.A., B.Sc., Assistant Government Geologist, Flinders Street, Adelaide—**Secretary**, 1930-35; **Council**, 1937-38; **Vice-President**, 1938-.

1925. *SHEARD, HAROLD, Nuriootpa, S.A.

1936. *SHEARD, KEITH, S.A. Museum, Adelaide, S.A.

1934. SHINKFIELD, R. C., Salisbury, S.A.

1928. SHOWELL, H., 27 Dutton Terrace, Medindie, Adelaide, S.A.

1920. SIMPSON, A. A., C.M.G., C.B.E., F.R.G.S., Lockwood Road, Burnside.

1938. SIMPSON, MRS. E. R., University, Adelaide.

1924. SIMPSON, FRED. N., Pirie Street, Adelaide.

1925. †SMITH, T. E. BARR, B.A., 25 Currie Street, Adelaide.

1936. SOUTHWOOD, ALBERT R., M.D., M.S. (Adel.), M.R.C.P. (Lond.), Wootoona Terrace, Glen Osmond, S.A.

1938. STEPHENS, C. G., M.Sc., Waite Agricultural Research Institute, Glen Osmond, S.A.

1935. STRICKLAND, A. G., M Ag.Sc. (Melb.), 11 Wootoona Terrace, Glen Osmond, Adelaide.

1922. SUTTON, J., Fullarton Road, Netherby.

1932. SWAN, D. C., M.Sc., Waite Agricultural Research Institute, Glen Osmond, S.A.

1934. SYMONS, IVOR G., Murray Street, Mitcham.

1929. *TAYLOR, JOHN, K., B.A., M.Sc., Waite Agricultural Research Institute, Glen Osmond.

1923. *TINDALE, N. B., B.Sc., South Australian Museum, Adelaide—**Secretary**, 1935-36.

1935. TRIGG, F., Government Printing Office, Adelaide, S.A.

1937. *TRUMBLE, H. C., D.Sc., M.Ag.Sc., Waite Agricultural Research Institute, Glen Osmond, S.A.

1894. *TURNER, A. JEFFERIS, M.D., F.R.E.S., Wickham Terrace, Brisbane, Q.

1925. TURNER, DUDLEY C., National Chambers, King William Street, Adelaide.

1933. WALKLEY, A., B.A., B.Sc., Ph.D., Waite Agricultural Research Institute, Glen Osmond, S.A.

1912. *WARD, L. KEITH, B.A., B.E., D.Sc., Govt. Geologist, Flinders Street, Adelaide—**Council**, 1924-27, 1933-35; **President**, 1928-30; **Vice-President**, 1927-28.

1936. WATERHOUSE, MISS LORNA M., 35 King Street, Brighton, S.A.

1931. WILSON, C. E. C., M.B.,B.S., "Woodfield," Fisher Street, Fullarton, Adelaide.

1938. WILSON, J. O., Nutrition Laboratory, University, Adelaide.

1935. WINKLER, REV. M. T., B.A., D.D., 20 Austral Terrace, Malvern, Adelaide.

1930. *WOMERSLEY, H., F.R.E.S., A.L.S., Museum, Adelaide—**Secretary**, 1936-37; **Editor**, 1937-.

1923. *WOOD, J. G., D.Sc., Ph.D., Professor of Botany, University, Adelaide—**Council**, 1938-.

ASSOCIATES.

1935. *FENNER, F. J., M.B., B.S., 42 Alexandra Avenue, Rose Park, Adelaide.

1936. SPRIGG, REGINALD C., Toddville Street, Seaton Park, Adelaide.

GENERAL INDEX.

[Generic and specific names in italics indicate that the forms described are new to science.]

CORRIGENDA

Page 154, line 3, and page 156, line 4, for *Entylenchus* read *Eutylenchus*.

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PART II